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A Summary of Current Program, 4/1/62;

and Preliminary Report of Progress

for 10/1/60 to 3/31/62

FOREST SERVICE

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

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This progress report is primarily a tool for use of Department scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs. The summaries of research progress include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting research results, issued between October 1, 1960, and March 31, 1962. This progress report was compiled in the Forest Service, U. S. Department of Agriculture, Washington 25, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
September 1, 1962

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ROCKY MOUNTAIN STATION

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INTRODUCTION

Within the Federal government, the Department of Agriculture has primary responsibility for forestry research and, within the Department, the Forest Service is assigned the mission of planning and carrying out forestry research programs. These programs provide the technical basis for protecting, managing, and utilizing all of the renewable resources of the National Forests and National Grasslands administered by the Forest Service. They provide the technical forestry information needed by the Department of the Interior and other Federal agencies having custody of forest and range lands. And, they are concerned with the forestry problems of State and private landowners and forest products industries.

As this report shows, the Department's program includes not only basic and applied research in forestry but also development of new products and techniques and dissemination of research results. The program is regularly reviewed to insure that balance and coordination are achieved. Goals for the next 10 years have been set forth in the National Forestry Research Program which is now under consideration by the President.

The Forest Service research staff numbers about 1,200 scientists, representing more than 40 scientific disciplines ranging from bacteriology to statistics. Their research is performed at the national headquarters at Washington, D. C.; at the Forest Products Laboratory, Madison, Wisconsin; at ten Regional Forest Experiment Stations which carry out projects at more than 70 other locations throughout the various States; and at the Institute of Tropical Forestry in Puerto Rico. In addition, there are two pioneering research units, one in forest mensuration and one in forest genetics. Most of the research is headquartered on or near the campus of a college or university.

The typical forestry research project is conducted in cooperation with others; usually the cooperator is another Federal agency, a State Agricultural Experiment Station, a university, or a private industrial firm or trade association. More than 1,000 formal cooperative agreements are in effect.

To an increasing extent, progress in forestry is contingent upon progress in forestry research. In recent years, there have been numerous instances of the successful application of research results. A few examples follow:

Direct seeding. The advantages of direct seeding of forest trees over the planting of nursery-grown seedlings have long been obvious. However, the results were so uncertain that direct seeding was seldom feasible. Continued research has led to new knowledge concerning the many seed and seed-bed variables involved. These variables now can be controlled in some situations and the acreage seeded by airplane and other broadcast methods is expanding rapidly, particularly in the South and the Northwest. In some southern States the acreage seeded annually now approaches the acreage planted and, nationally, the savings resulting from successful seeding in lieu of planting are close to $2.5 million annually.

New pulping methods. Forest products utilization research, leading to the development of the cold-soda and semi-chemical pulping processes, has made it practicable for the industry to use hardwood as a raw material. Low-quality hardwood trees, for which few markets previously existed, now can be logged for pulpwood. Today, about 60 pulp mills use these hardwood pulping processes and more than 2.5 million tons of semi-chemical or cold-soda pulp are produced annually.

Fire-fighting chemicals. Chemical retardants developed by research have led to an entirely new forest fire control technology. Few retardants were used before 1956 but, since then, the volume has grown rapidly. Last year, 8 million gallons were delivered on going fires, mostly by airplane. The search for new and better forest fire retardants is continuing.

Insect pest control. A number of cheaper and more effective insect control measures, developed in forestry laboratories, have been put into practice. A new spraying method, for example, has cut the cost of lodgepole pine needle miner control by two-thirds. Almost $100,000 was saved on one spray project alone by using the new method last year. In another instance, 33,000 bark-beetle-infested trees in California were treated by a new lindane method developed in the laboratory. Chemical costs per tree were $2.20 less than with the former method and other substantial savings in labor and transportation costs were made.

White pine blister rust. As a result of new findings in recent years, major changes have been made in action programs aimed at eradication of Ribes (currant and gooseberry bushes), the alternate hosts of white pine blister rust. Studies of microclimate have shown that the rust hazard in some areas is so low that white pine can be grown in these areas without eradicating Ribes. Based on this information, Ribes eradication has been stopped on 1-3/4 million acres in California and the Lake States at a savings of $225,000 annually. Also, new antibiotics developed in the Forest Service have recently made it feasible to grow white pine on one million additional acres which

were formerly considered lost to white pine because of extremely high rust hazard.

Naval stores. Some 15 years of forestry research has led to extensive change in gum naval stores techniques, particularly in the use of acid stimulation to increase yields from slash and longleaf pine. More recent refinements, such as the bark chipping technique have shown how to reduce labor requirements as much as 50 percent and, at the same time, make the worked-out tree saleable for other wood products.

* * * * * * * *

The 1961 meeting of the Forestry Advisory Committee, held in Washington, D. C., was devoted entirely to consideration of the proposed 10-year national program for forestry research. Hence this report on forestry research progress is somewhat more detailed than usual in order to provide background information on going research for those members who have joined the Committee during the two years since the last progress report was made.

I. TIMBER MANAGEMENT RESEARCH

A. SILVICULTURE

Problem

The broad field of silviculture includes the problems of growing and tending forest trees and stands from seedlings to sawtimber. It deals with reproducing forests both naturally and artificially, with intensive cultural measures for improving the yield and quality of forest stands, with methods for evaluating and improving the productive capacity of forest soils, and with harvest cutting methods required to perpetuate valuable species adapted to the site. Related to all of these problems are the basic physiological processes involved in tree growth.

Evaluation of soils and sites for the establishment, growth, and development of various tree species is basic to intelligent forest management. Knowledge of proper species or mixtures best adapted to particular sites is needed to guide regeneration programs, timber stand improvement operations, and stand conversion. The integration of fundamental and developmental research into systems for managing forest properties is the final phase of silvicultural research. Forest managers need to know how various prescriptions for better forest practices fit together into a unified management program. They also must know how other uses of the forest, such as water production, wildlife and domestic animal range, and recreation influence the management for timber production.

Program

A continuing program of research at all 10 Forest Experiment Stations and the Institute of Tropical Forestry in cooperation with various schools, State forestry groups, private industries, and other private forest landowners is conducted in this field of silviculture. Included is a comprehensive program of basic and applied research in seed production and seed handling, forest nursery practice, site preparation, direct seeding, and planting techniques to provide answers to the many problems in artificial regeneration. Studies of natural regeneration and the development and use of techniques--chemicals, controlled fires, and various types of equipment--pruning, thinning, weeding, and other stand improvement measures are carried on in all Experiment Stations.

A continuing, long-term program of applied research comparing different systems of management in different forest types and stand conditions is conducted at many of the Stations to provide practical answers to forest managers. Often these studies are in cooperation with private timber

companies who may provide forest land or purchase timber under contracts requiring special treatments and records.

The total Federal effort in silvicultural research in the United States amounts to about 230 man-years annually.

A program of research is also carried on under Public Law 480 in Brazil, Chile, Finland, India, Israel, Poland, and Spain.

Progress

1. Site Evaluation and Improvement

Site index measurements are usually used to estimate productivity of forest lands. However, non-forested areas and many disturbed stands are not suitable for site index measurement, so some indirect method must be used such as correlating site index with soil types or with certain measurable features of soil and topography. In southeastern Ohio, site index for black oak was found to vary so widely within soil types that identifying soil types will not alone provide an accurate estimate of site quality. Site index was found to be related to depth of surface soil, subsoil texture, subsoil stone content, aspect, slope position, and slope steepness. Using these features to modify existing soil taxonomic units, to describe new soil types or phases, or to apply in addition to present taxonomic units will provide greater precision in estimating site quality.

A comprehensive study of physical soil-site factors affecting site index of five important timber species was conducted in upland Piedmont forests. The trees and soils were sampled in 153 mixed pine-hardwood and hardwood stands, and detailed multiple regression equations were computed. These equations indicated that models used for soil-site investigations in subclimax softwood types will not produce useful guides for these climax forests. Nonetheless, the findings of this research provide some important facts about forest soil conditions that affect height growth of the species studied. Surface soil conditions and slope position proved to be important gauges of productivity for all species. Thickness and organic matter content of the A_1 horizon, thickness of the total A horizon, and percent sand in the A_2 horizon were correlated with yellow-poplar height growth. Percent organic matter in the A_1 horizon was negatively related to site index of oak and pine. Other findings include a positive effect of increase in slope percent on site index of black and scarlet oak, a positive effect of increasing latitude on site index of yellow-poplar, and higher site index for all species when yellow-poplar is present in the overstory.

A study in Georgia established a relationship between soil properties and site index for slash pine plantations in the middle coastal plain. The soil properties found to be highly correlated with height growth were the thickness of the A_1 horizon and the depth to a fine-textured horizon. Site quality increases as the thickness of the A_1 horizon increases. Optimum growth was found on sites having a depth to a fine-textured horizon of 28 to 30 inches. On sites where this horizon was shallower or deeper, an adverse effect on height growth was indicated. For field use of the data, a table and an alignment chart have been prepared to supply a direct height estimate based on the two soil variables. Average site values for the various soil series samples have been calculated and presented in tabular form.

In an effort to learn why yellow-poplar seldom grows on the wide flood plains of Piedmont rivers in the South, seedlings, planted in 55 gallon drums, were flooded for periods of 0, 1, 2, 3, 4, 7, and 14 days during the middle of March and latter parts of May and June.

Green ash and sweetgum seedlings were not affected by up to 14 days of flooding during any month. Yellow-poplar seedlings were not adversely affected by dormant season flooding; however, mortality occurred after 4 days of flooding in the early growing season (May) and after 3 days in early summer (June). Wilting and subsequent death of the above-ground portions of seedlings increased with lengthening of the period of inundation until after 14 days all were dead. Wilting occurred immediately after water was removed from the drums. Observations of a flooded plantation of four-year-old yellow-poplar saplings near a Piedmont river substantiated the findings of the controlled experiment. Trees, however, did not wilt until approximately 6 weeks after the flood. Sprouting of some seedlings and saplings from the root collars indicated that not all root systems were dead. Generally, top-kill followed deterioration of tissues in the lower portion of the stems.

In a study of the capabilities of forest sites for growing cherrybark oak, more than a thousand regressions were computed for the relations between various physical and chemical properties of the soil, and site index of the trees, as measured on 285 sample plots in the mid-South. From these analyses three methods of estimating site index of cherrybark oak were derived. In method I,depth of topsoil, depth of mottling, and depth to hardpan are sampled, and site index is then read from a table computed from the best regression equation using these factors. This is the most reliable and objective of the three methods. In method II, texture, internal drainage, amount of erosion, presence of fragi-pan, and inherent moisture condition of the site are determined in the field, and site index is then obtained from a key. The field determinations of soil properties are less precise than in method I, and the resulting estimates of site index indicate a range of 10 feet for any soil class. The third method merely requires that the user identify the soil series and moisture

phase of the site and then consult a table for mean index, standard deviation, and range. This method is the least reliable of the three, but it is the simplest to use when a soils map is available for the area in question. If such a map is lacking, the soil-site must be identified by a qualified soil scientist.

During a dry year in east Texas, soil moisture and hence survival of planted loblolly pines were improved by scalping, mulching, and chemical treatments that controlled the weeds and grasses on a typical abandoned field. Scalping removed about three inches of surface soil; when Bermuda grass and other plants invaded they were weeded out. The chemical was Vapam, a soil sterilant containing 32 percent sodium methyl dithiocarbamate. Mulches were of pine needles. There were 6 treatments or combinations of treatments. Survival was best on scalped and mulched plots. These were also the plots with the most soil moisture during July and August, when rain was scant. Seedling heights after the first growing season averaged 1.1 feet on unmulched plots and ranged from 1.3 to 2.1 feet for mulched treatments. As droughts are frequent in east Texas, it appears unwise to plant pines without some form of site preparation.

Better knowledge of the mycorrhiza-forming fungi is important if full use is to be made of their beneficial effects on tree seedlings. A study at the Pacific Northwest Station added 26 species of the fungi to the list of suspected mycorrhiza formers on Douglas-fir, Sitka spruce, and ponderosa pine. Suillus granulatus, usually considered a pine associate, was found with Douglas-fir. This information adds to knowledge of both fungus and tree ecology and provides a basis for research on the comparative effects of different mycorrhizal fungi on the tree hosts.

Red alder (Alnus rubra) is the most important hardwood tree of the Pacific Coast, in terms of not only commercial value but also wood volume and wide distribution. Apart from its economic value, red alder is of special interest as a possible soil-improving hardwood tree in a region where forests are predominantly coniferous. Research with species of alder other than A. rubra has demonstrated that these trees harbor bacteria which fix atmospheric nitrogen in root nodules, thereby increasing soil nitrogen, and in turn improving the growth of associated plants. However, until now we have had no firm knowledge of this trait in A. rubra. A plantation of Douglas-fir in southwestern Washington was interplanted after four growing seasons with red alder. When the fir was 27 years old, comparison of the mixed stand with an adjacent portion of the same fir plantation indicated increases in form class, average limb length, foliage nitrogen content, and diameter and height growth rate for dominant fir grown with alder. Total nitrogen in the upper 3 inches of the soil profile was greater beneath the mixed stand but numbers of soil fungi were less. Improvement in nitrogen content of the soil and in growth of associated conifers indicates the influence of red alder is similar to that reported for other species of Alnus.

Information on soil and topographic features in relation to timber productivity in the Black Hills and Bear Lodge Mountains now provides a basis for estimating site index for ponderosa pine. On crystalline soils, percent of slope, aspect, location on the slope, and soil depth of the C horizon were significant variables. On limestone soils location on the slope and soil depth to the C horizon were the two important variables. Equations derived from the study are useful not only for determining site index of stands as a basis for decisions on thinning and pruning, but they also provide a means of determining site productivity on proposed planting areas devoid of tree growth.

A study was made from 1946 to 1956 of the effect of prescribed burning on soils beneath loblolly pine stands growing in the level, lower coastal plain of the southeastern United States. Data were collected on two experimental areas located about 30 miles apart in South Carolina. The sites are comparable in that they have similar topography and surface soil texture. Annual and periodic fires over a ten-year period had no significant influence on the physical properties of the soil. Mineral elements, nitrogen, and organic matter tended to increase in the surface 4 inches of the burned plots.

2. Seeding and Planting

a. Seed handling. Knowledge of metabolic processes involved in the activity of pine seeds during germination may give some clues to better methods of handling and treating. One of the metabolic processes is the nitrogen cycle with its conversions of amino acids. To study this cycle, ornithine labelled with radioactive carbon was fed to germinating pine seed. Ornithine had previously been shown to be a source of nitrogen in culture studies. Labelled carbon appeared in both citrulline and arginine, which are common intermediates in the ornithine - urea cycle. However, neither labelled or non-labelled urea was found, so the ordinary cycle was not established for germinating pine seeds. The compound adenine has been associated with growth promotion in some plant tissues and hence is of interest in the general problem of seed germination. The metabolism of adenine in pine embryos was followed by means of radioactive carbon in the molecule. Intermediates identified in the metabolism of adenine showed that the metabolic pathway followed that known in other tissue. Further research will be needed to reveal its relation to seed germination.

Treating seed with hydrogen peroxide is a satisfactory substitute for stratification to break dormancy of some tree seed. Soaking loblolly pine seed in a 1-percent solution for 48 to 96 hours increased the speed of germination to that of stratified seed but had no effect on total germination. Soaking slash pine in a similar solution for 24 to 48 hours increased both the rate and extent of germination beyond that of stratified seed. However storage of the seed for 3 days following treatment produced a significant

reduction in the germination rate. Seeds of subalpine larch germinate slowly or not at all without pretreatment. Soaking these seeds in a U. S. P. 3-percent solution of hydrogen peroxide for varying lengths of time was tried as a method of overcoming dormancy under laboratory conditions. Soaking the seeds for 24 hours stimulated significantly more germination than 18-, 12-, or 6-hour soaking periods. Non-treated seeds did not germinate. This is the first reported success in breaking dormancy of subalpine larch seed. Pretreating larch with H_2O_2 facilitates rapid germination and can be performed by persons inexperienced in seed testing.

Hydrogen peroxide has also been found to be effective in surface sterilizing seed coats. Unlike most other compounds used for this purpose, H_2O_2 need not be washed off the seed after treatment because it rapidly breaks down into harmless compounds. Moreover, soaking in 35 percent H_2O_2 for a half-hour or more stimulated germination of seed of several conifers. The technique is efficient and easy and offers the bonus of more rapid germination.

Light, temperature, and moisture are important factors in the germination of some tree seed. Yellow and paper birch seed, which usually require stratification, will germinate in water if exposed to 80-foot candles of cool-white fluorescent light for 8 hours per day. This technique will simplify germination test of these species by eliminating the need for stratification, and shortening the time involved in seed testing.

The germination of Virginia, loblolly, and white pine seed is affected by red and far-red light. After a few days of wet prechilling, germination could be induced in all species by exposure to red light. These actions are repeatedly reversible. They are controlled by a phytochrome pigment in the seeds. Sensitivity of the seeds to red light was increased, and sensitivity to far-red was decreased, with increasing periods of wet prechilling. Loblolly and white pine seeds required longer prechilling than Virginia pine seed to attain equal sensitivity to red light. These results not only make it possible to reduce presowing-treatment time but may be bases for new investigations in seed germination.

The length of time loblolly pine seed are stratified in moist vermiculite at 30° F. affects the time required for germination but not total germination. The time required for 85 percent of the seed to germinate decreased from about 90 days for seed not stratified to about 10 days for seed stratified for 60 days. Reducing this time for germination is particularly important in direct seeding because most of the germination will take place soon after seeding and new seedlings will be better established and withstand adverse conditions that may develop later in the season.

New information on seed storage now makes it possible to collect extra seed when seed crops are good and keep it for use during non-crop years. Red pine bears seed crops infrequently and consequently seed are sometimes not available or very expensive. If stored at a moisture content of 6.5 percent or less and at temperatures of 32° to 39° F. the seed will remain viable for at least 10 years and probably for many years. Longleaf pine seed should be dried to about 5-percent moisture if they are to be stored at room temperature. An 8-percent moisture content is best if they are to be stored at below zero temperatures. Freezing temperatures not only help retain viability but also shorten the time needed for germination. This information will be a big help in the artificial regeneration of this species.

b. Direct seeding. Direct seeding appeals to the Nation's landowners and foresters as a relatively inexpensive means of reforesting cutover and denuded forest lands. Marked success has been achieved with certain species in some sections of the country, particularly the South, when suitable site preparation and protection measures developed through research are applied. Each year research is adding new information that makes it possible to intensify and extend this method of artificial regeneration.

Condition of seedbed is an important factor in the success of direct seeding. On a clear-cut Virginia pine stand in Maryland, areas disturbed by logging and areas burned had four times as many Virginia pine seedlings as undisturbed areas 2 years after seeding. Height growth was best on the burned areas.

In central Louisiana disking before seeding benefits slash pine. In the dry growing season of 1954, first year mortality averaged 93 percent on unprepared plots, as compared to 62 percent on disked strips. In 1955, a wet year, mortality was less than 5 percent on disked and unprepared seedbeds, but losses over the next 4 years were considerably less on disked seedbeds. At age 5 years, pines averaged 8.2 feet tall on the disked strips, and 5.4 feet on undisked plots. Planted trees on adjacent plots reached 8.6 feet in 5 years, or only 0.4 foot more than seeded pines on disked strips, despite a 1-year difference in age from seed.

Similar results also were obtained with loblolly pine in central Louisiana. After 9 years the 350 well-spaced dominant trees on disked areas averaged 4 feet taller and 0.6 inches larger in diameter than similar trees on non-disked areas. This difference is equal to more than one year's growth and easily enough to repay the $2.00 per acre cost for disking. As with slash pine the seeded trees on disked areas compare favorably with those in nearby plantations.

In northwestern California, encouraging results have been obtained in the use of a formulation of endrin, arasan, asphalt, and aluminum dust to protect Douglas-fir seed from seed-eating rodents. The treatment not only protected seed from rodents known to be present but had no adverse effect on seed germination and seedling growth. Of the seed spots not washed away or covered by deposited soil, 83 percent had seed germinate and 71 percent were stocked at the end of the first year. Although these results provide a means of reducing the loss of direct-seeded Douglas-fir seed to rodents, the problem reducing losses due to soil movement still must be solved.

In north central Arizona, ponderosa pine should be seeded late in June. In this area these seed do not germinate until the soil is continuously warm and moist. These conditions first exist when the summer rainy season begins usually in July. Earlier seeding does not result in earlier germination. Later seeding results in poorer seedling establishment and higher mortality during fall droughts.

Direct seeding shortleaf pine in the Missouri Ozarks was more successful when done in December than in February or March. Deadening the overstory trees by girdling just prior to seeding gave the most consistent results. Cutting or girdling the overstory trees a year before seeding resulted in a rank growth of sprouts and weeds that reduced the number of seedlings. Sowing enough seed to obtain several seedlings per spot may be an important key to successful direct seeding of shortleaf pine. Spots containing at least three seedlings in the first year remained stocked and generally had taller trees after 14 years than those with fewer seedlings. Stagnation was no problem.

In a seed-spotting study of ponderosa pine, western white pine, and Engelmann spruce in northern Idaho and southeastern Washington, growth rate decreased with increased number of seedlings per spot. However, a satisfactory stand will develop and thinning is not recommended.

In some parts of the loblolly pine range, areas to be seeded are sometimes flooded for several days after heavy rains. A study in Arkansas has revealed that loblolly pine seed stratified in wet sand for 30 days and coated with latex were not adversely affected by flooding with 4 inches of water for a period of 14 days. This information will make it possible to extend the direct seeding of this species to include those areas that are flooded for less than 2 weeks at a time.

Direct seeding of hardwoods is not as far advanced as for the conifers but some progress is being made. Results of three tests of direct seeding of oaks, one in the Piedmont and two in the mountains of North Carolina, indicate that white, northern red, and black oaks can be successfully regenerated by direct seeding. Best results were obtained with acorns

that were planted in mineral soil. Screen protection, though effective, proved to be unnecessary in the Piedmont study where all the acorns were planted in the soil. In the mountain studies screens were ineffective; survival of acorns on the surface was very low regardless of screen protection, while results were good with acorns planted in the soil, whether screens were used or not. Acorns used for direct seeding should be treated for weevil control and planted 1 to 2 inches deep in mineral soil. Planting may be done either in the fall or in the spring.

c. Species adaptability. A knowledge of the suitability of species to various sites and conditions is of vital importance to land managers engaged in forestation. Studies point the way to extending trees safely beyond their presently known ranges for increasing production or quality or to combat particularly severe conditions. For example, deodar is a conifer from the Himalaya Mountains that has commercial value. At San Dimas Experimental Forest, where the annual rainfall is 28 inches, a 31-year-old plantation situated at an elevation of 2,700 feet was examined and measured. The average d.b.h. and height of dominants and co-dominants were 12.8 inches and 76 feet, respectively, and form of the trees was mostly good. Growth is rather impressive and indicates that the species may have value for forestation purposes in parts of California.

A 10-year study on southeast Kansas spoil banks showed that trees from direct-seeded walnuts were significantly taller than planted trees; survival and form were essentially the same in both cases. Height growth differences may have been due to cutting or breaking the taproots of nursery-grown trees with subsequent development of lateral roots in the field. Such trees cannot obtain soil moisture as well as the direct-seeded walnut trees with normal strong taproots.

An examination of old plantings in north Mississippi and west Tennessee showed that loblolly pine, though well out of its commercial range, outgrew shortleaf pine. In 23-year-old plantations in Benton County, Mississippi, loblolly trees were 63 feet in height, the tallest shortleaf 48 feet. Pulpwood volumes per acre averaged 42.8 cords for loblolly and 27.5 cords for shortleaf. Also, vigorous growth of plantations near Jasper, Arkansas, indicates that loblolly may be suitable for short rotations, even though there, too, it is outside its natural range.

In another study on the deep sands of western Florida, sand pine planted on unprepared sites grew well with little or no release from competing vegetation. Eight years after being planted, sand pine averaged 13.3 feet in height, slash pine 3.8 feet. The survival and growth of unreleased longleaf, loblolly and shortleaf pine were extremely poor. The ability of sand pine to compete successfully with oaks and wiregrass has special significance for sandhills landowners, many of whom are unable or unwilling to incur the costs of the intensive site preparation needed for other species.

The search continues for tree species best suited to reclaiming strip-mined spoil banks. Black locust has been one of the most successful for improving the site, but the locust borer usually prevents it from growing to product size. European alder is also a nitrogen-fixer and has been found to survive and grow well on acid spoil banks. Moreover, it has no serious insect pests, has good form and should yield pulpwood or sawtimber, and may be a suitable replacement for black locust as a nurse tree.

In Mississippi introduced Euramerican hybrid poplars have, with one exception, proved inferior to native cottonwoods in survival and growth, and none has proved superior. Several locally selected clones are making outstanding early growth; the best for any individual tree has been 30 feet in height and 4.8 inches in d.b.h. in the first 2 years.

White pine is believed formerly to have been more abundant than now in northern Appalachian forests, and is considered to be more productive on lower quality sites than hardwoods. The problem is how to introduce more white pine, and where can it be done most easily and successfully. A study in West Virginia showed that cutting or deadening the overstory is essential for successful underplanting of white pine, and that the better the site, the more difficult it is to establish the pine because of the increasing competition from understory shrubs and sprouts. At oak site indexes of 40 to 50, many planted pines in the test plots still were free to grow and thrifty after 6 years; at indexes of 50 to 60, understory hardwood growth became increasingly competitive and more of the pines were suppressed. Without afterplanting release treatments, the marginal oak site index for introducing white pine is about 55 feet.

d. Planting. Research continues to supply new information to improve planting as a means of artificial regeneration. Ten years after planting, pure stands of black walnut were found to have better survival, greater height, and better form than walnut grown in mixture with black locust. In mixed stands without black locust, however, the walnut grew almost as well as in pure stands. Mixed plantings are recommended because they usually result in earlier harvest of merchantable products and faster improvement of site. However, when comprising only 25 percent of a mixture, locust had a definite detrimental effect on walnut. A 50 percent locust component in the stand also reduced survival and growth of redcedar, green ash, bur oak, and sycamore. On the basis of this study, black walnut should be planted only with bur oak, sycamore, redcedar, or green ash on spoil banks in southeastern Kansas. A logical mixture might consist of equal amounts of the selected species.

Two studies conducted in the Piedmont region of North Carolina with yellow-poplar again show how important it is to grade seedlings. Survival after 3 years for seedlings 0.25 inches at the root collar was lower than that of larger seedlings. Seedlings below 0.20 inches were not acceptable.

On the basis of these studies tree planters would do well to discard yellow-poplar seedlings much below 0.25 inches at the root collar. Also, nurseries should improve growing conditions so that a higher proportion of large seedlings are produced.

Fourth-year height measurements indicate that the fertilized yellow-poplar seedlings are not only maintaining their growth advantage, but are actually showing increases in height advantage each year over unfertilized seedlings. Similarly, mean height differences among plots fertilized at different rates are seen to increase with age. An estimate of optimum rate of fertilizer application was calculated by expressing total height as a quadratic function of fertilizer applied. The value obtained, 1,200 pounds of diammonium phosphate per acre, must be considered a rough estimate because it falls outside the range of the fertilizer rates applied. Nevertheless, it should be helpful in planning future plantings of yellow-poplar on well-drained small stream bottoms of the Piedmont.

The coarse, shallow, and highly desiccative soil on steep terrain and low summer rainfall combine to make severe planting sites in central Idaho. Until 1954 no ponderosa pine plantations on these sites could be considered successful. A joint planting study by the National Forest Resource Management and the Intermountain Station evaluated the effects of site preparation, condition of the planting stock, and care in planting. The study showed that the highest 5-year survival, 95.4 percent, was attained on ground prepared by stripping with a bulldozer and trenching with a plow. The lowest 5-year survival, 11.6 percent, was confined to trees planted on unprepared ground. This pilot-size experiment developed a successful planting method which has stimulated renewed effort throughout the ponderosa pine region in places where planting had largely been given up as a reforestation method.

To provide guidelines in determining the nutrient status of young trees, loblolly and Virginia pine seedlings were grown in sand culture at Beltsville, Maryland, and supplied with various amounts of potassium, magnesium, and calcium. Seedlings not supplied with enough potassium developed purplish and brownish needles, which finally died. The potassium concentration in the needles of deficient seedlings was usually less than 0.26 percent. Insufficient magnesium led to yellowing of the needles and terminal dieback. The magnesium concentration in the foliage of such deficient plants was less than 0.08 percent. Seedlings deficient in calcium showed yellow mottling of the needles and resin exudations on the buds. Needles on calcium deficient plants were thicker and shorter than normal and had a calcium concentration of less than about 0.03 percent. Although visual symptoms indicate that there probably are nutritional disorders, corrective measures should be applied without more definitive foliar analyses of the trees.

The possibility of supplying phosphorus to trees by an aerial spray was shown by a study of foliar application of phosphorus at Beltsville, Maryland. The upper needles of 3-month-old loblolly pine seedlings were dipped in a 0.5 molar diammonium phosphate solution, tagged with radioactive phosphate. This dip simulated a spray. Within 24 hours radioactive phosphate was found in the root tips of the seedlings and a maximum concentration occurred in 48 hours. Height growth after treatment was twice that of seedlings grown without the foliar dip but was only 60 percent of that of seedlings supplied with adequate phosphorus in the nutrient solution. Five weeks after treatment, 65 percent of the phosphorus found in the new needles had been translocated from that applied to the older needles. The study clearly demonstrates that phosphorus may be supplied to the tree through the foliage.

3. Natural Regeneration

a. Seed production and dispersal. Seed production, a prerequisite to satisfactory natural seedling regeneration, varies greatly from year to year, stand to stand, and tree to tree. Several studies have contributed information of value to forest managers concerning the factors that affect seed production, dissemination, and quality.

A 13-year study of loblolly pine seed production in the Coastal Plain of Virginia showed that: (1) cone production in unmanaged stands does not usually start until the trees are 30 to 50 years old and thereafter increases with tree age until tree maturity, (2) releasing young seed trees increases seed production, starting the third year after release. The increase is most noticeable during poor seed crop years, (3) soundness of seed increases with size of the seed crop, and (4) under average conditions, 8 free-growing mature seed trees per acre provides an adequate seed source.

During the 10-year period, 1950 to 1959, the seed crop of thinned young-growth Douglas-fir stands in western Washington ranged from about 200 (1958) to over 560,000 (1959) seed per acre. The 1959 crop was about seven times greater than the next largest crop. Seed production was about 100 percent greater in the thinned than in the unthinned stands during the good seed year but was not influenced by thinning during poor seed years. The percent of seed that were viable increased with an increase in size of seed crop. It was essentially the same (about 51 percent in 1959) for thinned and unthinned stands.

Infrequent seed crops and poor quality of Douglas-fir seed also are deterrents to natural regeneration in northwestern California. There was only one abundant seed crop in this area during a 7-year study period. Even in this good seed year only about 25 percent of the seed contained fully developed endosperms and embryos. Seed dispersal drops off rapidly as the distance from seed source increases so that 300 feet from

the edge of a timber stand is about the maximum distance for effective seeding.

In a recent study in southern Indiana it was found that it takes about 50,000 yellow-poplar seed per acre to provide adequate regeneration, primarily because of the low viability of the seed. It averaged only 7 percent during the study period. A good seed tree will provide an adequate seed supply to a distance of about 150 feet south and southwest and about 350 feet north and northeast of the tree. In stands with scattered seed trees, patch or group cuttings should be shaped accordingly to take advantage of prevailing winds. Scarification within the above limits is not necessary but is beneficial farther from such trees where seed fall is below 50,000 seed per acre.

An understanding of seed production and dissemination is also basic to prescribed cutting methods to obtain natural regeneration of ponderosa pine. In northern California stands were cut to leave an average of 2, 6, and 7 ponderosa pine seed trees per acre. These trees produced an estimated 15,000, 30,000, and 60,000 seeds, respectively, in 1960, a good seed year. One year later there was an average of 1,900, 4,000, and 5,000 ponderosa seedlings on the acres thinned to 2, 6, and 7 seed trees per acre. The lower stocking of 1,900 seedlings per acre is considered adequate for average conditions in this area.

Winter flooding is an inexpensive treatment that has real promise for dual-purpose management of bottom-land hardwood stands along the central Mississippi Flyway for timber and game crops. A 4-year study in pin oak stands in southeastern Missouri has shown that: (1) pin oak trees survived the fall-winter flooding necessary for shooting area development, (2) flooded areas produced more sound acorn mast than the non-flooded areas. The total crop was about the same on the two areas (10,000 to 200,000 acorns per acre) but on the flooded area a lower percent was infested with insects, (3) natural regeneration of pin oak was much lower on the flooded area, probably because most of the acorns were consumed by the ducks, (4) flooding may have to be discontinued for 1 to 3 years when it is time to regenerate the stand, and (5) wildlife management objectives and timber management objectives for such areas are compatible.

b. Regeneration cuttings. The difficulty of controlling natural regeneration so that the next stand will contain the wanted species, varies greatly with forest types and growing conditions. For example, a bumper acorn crop in a good red and white oak stand (with scattered sugar maple, yellow-poplar, American elm, black cherry, and red maple) at the time of clear-cutting will not assure adequate natural seedling regeneration of the oaks. Seven years after clear-cutting such a stand in Michigan, there was a fully stocked new stand but its composition had little or no resemblance

to that of the stand before cutting. The important species forming the new stand were white oak, sugar maple, American elm, black cherry, and red maple in that order. More than 97 percent of these new trees were of seedling origin and less than 3 percent were of sprout origin. Among the sprouts, red oak was the most abundant and the tallest. Two-thirds of the red oak and red maple, and one-fifth of the yellow-poplar had been severely browsed by rabbits. If such oak stands are to be perpetuated through natural regeneration, the rabbit damage will have to be reduced and intensive cultural practices, such as early cleanings, will have to be used to bring the oaks through the establishment and early growth periods.

Natural regeneration of Northern Appalachian hardwood stands can be satisfactorily controlled by varying the degree of cutting the overstory. In West Virginia, for example, a study of reproduction 5 and 10 years after cutting showed that an abundant crop of new trees of commercial species becomes established after most methods of cuttings. Heavy selection cuttings favor the intolerant species such as yellow-poplar and a high percent of stems of sprout origin. Light selection cuttings favor the tolerant species such as sugar maple and beech. Group-selection cuttings favor the somewhat more intolerant species such as yellow-poplar, white ash, and black cherry. In most of these stands, the desired composition of the next stand can be obtained by proper method of harvest cuttings followed by stand-improvement measures to favor desired species as needed.

Survival and growth of forest trees depend on adequate soil which provides not only mechanical support but a medium to furnish moisture and nutrients. In the Intermountain region, extensive areas of ponderosa pine forests are on shallow soils. These shallow soils combined with frequent severe climatic and physiographic conditions, result in critical growing conditions for seedlings during establishment and for trees during their lifetime. Where soils less than 20 to 24 inches deep support the ponderosa pine type in which harvest cuttings are contemplated, cutting should be altered so that the site is never clear cut and a cover of trees is left.

Natural regeneration is a major means of reproducing loblolly pine in managed stands in the Virginia-Carolina Coastal Plain area. Well-stocked loblolly pine stands frequently produce ample seed crops. During the last 15 years a 40-to 50-year-old managed stand in South Carolina averaged about 350,000 sound seed per acre per year. Five of the crops were considered bumper crops, seven were good, and only three were classed as poor. Even during the poorest year enough seed were produced for management purposes. This fairly dependable seed supply makes it possible to plan for brush control and seedbed preparation before seedfall and to start clear-cutting immediately after peak of seedfall, usually the latter part of November. This procedure, gives promise of becoming a popular regeneration technique in this area.

c. Aids to natural regeneration. New information on controlled burning as a means of site preparation to favor natural regeneration is demonstrating the importance and possibilities of extending the use of this silvicultural tool. In south Mississippi a September burn to remove a 6-to10-year accumulation of grass and needles in an unevenly stocked second growth longleaf pine stand resulted in a 300 percent increase in number of seedlings and a better distribution of seedlings over the burned area. In tests of various combinations of burning and scarification to establish advance pine reproduction in the last strips to be cut in a strip-cutting in pure Virginia pine in Maryland, all treatments substantially increase the amounts of reproduction over untreated control areas. Burning alone gave adequate seedling establishment, and was more effective than scarification in reducing understory hardwood competition. Suggested procedure is to burn in a good seed year shortly before the cones open, then harvest the overstory 1 or 2 years later.

Basic factors influencing seedling establishment in the western larch--Douglas-fir type of the northern Rocky Mountains must be known before cutting methods can be recommended that will insure adequate regeneration. Studies were started in 1959 to determine causes of seedling mortality in western larch, Douglas-fir, Engelmann spruce and subalpine fir. Two-thirds of the seedling losses were caused by physical factors, chiefly insolation and drought. Most of the deaths occurred during mid-July to mid-August when rains had ceased, soil surface temperatures were high, and soils had dried. The greatest insolation losses were recorded on south and west aspects, mostly in July. Drought losses, on the other hand, were found mainly on the northerly aspects in August. The remaining one-third of the mortality was attributed to biotic agents, such as fungi, birds, and rodents. All species survived better on northerly than on south and west aspects.

Because of the thick humus usually found under northern softwood stands, desirable advance reproduction often is sparse and poorly distributed. In a study of several seedbed treatments under dense softwood stands near Bangor, Maine, removing the humus or mixing it with the underlying soil greatly increased catches of spruce and hemlock seedlings. Hardwood litter, when present in quantity, may smother many softwood seedlings during their first winter. The study results indicate that, in selection management of softwood stands, the following recommendations should be adopted insofar as is practicable: (1) log when the ground is not frozen or snowcovered, so as to achieve maximum disturbance and mixing of the humus; (2) log during good seed years; and (3) remove hardwoods.

Bulldozing strips about 10 feet wide and 7 to 17 inches deep resulted in satisfactory regeneration of cottonwood in a cutover riverfront hardwood stand in Mississippi. Plowed strips improved regeneration some but disking was not satisfactory largely because of competition from rank growing weeds. In another bottom land in Mississippi, the above-ground

parts of a cutover hardwood forest were removed with a bulldozer without much disturbance of the roots. New sprouts and weeds soon occupied the clearings and at the end of 5 years, the areas were dominated by bitter pecan and green ash sprouts, some of which were 15 feet tall. In most cases this type of site preparation will result in a new stand dominated by those species which are the most prolific sprouters.

The economic returns from managing the northern hardwood forest in Upper Michigan can be increased greatly by increasing the proportion of yellow birch in the stands. This species is in great demand for veneer and the current stumpage price is more than twice that of sugar maple, the next most valuable species. A study in northern Michigan found that the seed supply was usually adequate and that the silvicultural practices most favorable for increasing the proportion of yellow birch in these stands are: (1) reduction of the overstory canopy to let through about 50 percent of full sunlight; (2) scarification to expose mineral soil on at least 50 percent of the area; and (3) a salvage cutting 3 to 5 years after the initial cut to gradually increase the amount of light to maintain growth of established seedlings. These measures are a significant departure from the selection system commonly used in managing the tolerant species of northern hardwoods such as sugar maple.

4. Silvicultural Systems

Modification of the water-absorbing capacity of the soil is a critically important change that can take place when forest stands are harvested. Infiltration studies were made annually during a 5-year period in a mature western larch--Douglas-fir stand following timber harvest and a slash treatment. These studies were made on soil showing four surface conditions; tractor skid roads and scarified, broadcast burned, and undisturbed areas. The first year after logging the infiltration capacity of skid roads, scarified areas, and broadcast burned surfaces averaged 4.1, 15.4, and 62.5 percent, respectively, of the capacity of undisturbed soil. During the succeeding 4 years the water intake capacity of scarified and lightly burned surfaces improved fairly rapidly, but the skid roads showed virtually no improvement. Because both soil scarification and burning aid establishment of western larch and Douglas-fir reproduction, excessive soil compaction must not be permitted during slash treatment with heavy machinery. Impairment in water-absorbing capacity of the soil for long periods by compaction can lead to high runoff rates and soil erosion.

Dwarfmistletoe is a major pest of ponderosa pine in the West. To study the feasibility of silvicultural control, ponderosa pine stands were treated by one of 3 levels of harvesting. In the first type of cutting, 77 percent of the volume was removed and the percent of mistletoe infection was reduced from 44 percent to 10 percent. In the second type, comparable data were 73 percent and 50 percent to 5.5 percent. In the third type, the

figures were 35 percent and 40 percent to 36 percent. Ten years of study show that in severely diseased stands such as these, little control will be accomplished without heavier than normal cutting, perhaps coupled with follow-up cutting about 5 years after the initial cutting to remove trees with latent infections.

Convincing small woodland owners of the profitability of management is a challenging problem. Therefore, foresters are focusing considerable attention on cost and returns of management in these small tracts which collectively constitute a substantial part of the Nation's commercial timberlands. A case history of over 10 years for a tract in the Coastal Plain of South Carolina shows that the owner can derive an annual income while improving the value and increasing the productivity of his woodland. Net returns averaged over $11.00 an acre a year, chiefly from pine sawlogs and pine pulpwood. Additional income resulted from the sale of low-grade hardwoods logs, pine posts, and gum pulpwood. By doing his own logging the owner can substantially increase returns. When sold at the roadside, the products brought $2,929 over a 10-year period, an increase of $1,363 above the value of the stumpage. Cash costs of $413, primarily for rental of a tractor to skid sawlogs, reduced this return to $950. Since 859 man-hours were spent in logging during the 10 years, the average return for labor was $1.11 per hour. During the 10-year period of light but profitable improvement cutting, the growing stock increased in value $67.50 per acre, mainly through growth.

A tremendous impetus toward the management of hardwood forests on the better hardwood sites has developed in the Lower Mississippi Valley, Lower Piedmont, and Southern Coastal Plain from Virginia to Texas. Forty-five million acres now occupied by good southern hardwoods should be managed for continued production, and 25 million more acres are well suited to growing good hardwoods if given appropriate treatment. As an aid in the management of these forest types, the Southern Station has published Agriculture Handbook 181, "Management and inventory of southern hardwoods". This well-illustrated book begins with such topics as the relationship of the many species to the sites on which they grow, stand origins, silvical requirements, damaging influences, and general principles of utilization. Later chapters cover techniques for inventorying and managing different types of stands, and the yields that can be expected. Five systems for making inventories in hardwood stands are described--one for reconnaissance, one for timber sales, and three point-sampling procedures for estimating growth and stand development. Methods of adequately classifying tree quality or value are included in each system. Procedures for use of modern data processing methods are discussed.

Single-tree selection in a mixed-oak uneven-aged stand in southern Illinois is not a satisfactory system for sustained yield. Even though the 3-year cutting cycle provided a continuity of yield, increased the net growth and quality of the stand, and made a satisfactory net return, this type of cut

did not provide for adequate regeneration of the desirable species, such as yellow-poplar and oaks. On the basis of this study, cutting cycles should be longer and cutting should be made by groups to provide openings at least one-tenth acre in size.

5. Stand Improvement

a. Pruning. An evaluation of the opportunities, costs, and values of pruning commercial species in the Intermountain region showed that if the present difference in lumber prices due to quality continues, pruning will increase log values by about 50 percent. This is particularly true if pruning effort is concentrated on the more valuable species growing on the better sites. The combined investment in thinning and pruning in Northern Rocky Mountain conifers is estimated to earn 3 to 3-1/2 percent on good sites, 2-1/2 to 3 percent on medium sites, and about 2 percent on poor sites.

In Georgia, it has been shown that 3 to 6 minutes spent in pruning widely spaced, fast-growing loblolly pine trees can increase the value of wood 50 percent by the time the trees are 40 years old and 16 inches d.b.h. In pruning such trees, main consideration should be to prune when the trees are 4 to 5 inches d.b.h. so that the knotty core will be small, early growth rate in the lower trunk and consequently trunk taper will be reduced, and the cost will be kept to a minimum.

Differences in the rate of wound healing and amount of sprouting on pruned cottonwood and willow oak trees have been demonstrated in the Mississippi delta. Because of fast growth rate, about 90 percent of the wounds made by removing live and dead cottonwood branches up to 3 inches in diameter were healed in 2 years. Development of sprouts on the pruned trees was not serious. On willow oak, about 90 percent of the wounds made by removing live branches and 69 percent of those made by removing dead branches up to 2 inches in diameter were healed at the end of 3 years. One year after pruning, 40 percent of the trees had at least 20 new sprouts which offset most of the beneficial effects of the pruning. Until some method of reducing sprouting is found, pruning of willow oak may not be worthwhile.

Epicormic branching, common in red alder, has long been considered a deterrent to the production of clear wood after pruning this species. The effect of pruning on formation of clear wood was determined by examining trunk sections from a 43-year-old red alder stand that had been pruned at age 21. Exposure of knots by sectioning showed that clear wood began forming over pruned branch stubs within 2 years, but gains in wood quality were frequently offset by the development of epicormic branches. Such branches developed from dormant buds. It is believed these buds are normally held in check by growth inhibitors produced in leaves or buds

of nearby branches. Until more is learned of the basic cause and control of epicormic branching, the desirability of pruning red alder remains questionable.

The great demand and high prices paid for clear walnut wood makes black walnut trees good candidates for pruning. Bole sprouts from dormant buds, rather than tree growth or decay and insect hazards, limit the degree of pruning. Studies in Kansas have shown that as much as 75 percent of the crowns of 3- to 5-inch, 14-year-old planted trees can be removed without seriously retarding growth. By the end of 5 years, clear wood had formed over most of the wounds and there was no evidence of decay or insect damage. However, amount of sprouting increased with degree of pruning. One year after pruning more than 50 percent of the trees with 75 percent of the crown removed had bole sprouts, whereas only 6 percent of those with 25 percent of the crown removed had sprouts. Most of the sprouts developed on the west and south sides of the trees and on the sides facing openings in the stand. Paradoxically, trees that need pruning most should be pruned least. Until some method of controlling sprouting is available, not more than 25 percent of the live crown should be removed at any one time. Thinning to increase tree growth should not be done for a few years before or after pruning, and then preferences should be given to removing trees on the north and east sides of pruned trees.

b. Herbicides for killing unwanted woody plants. Continued progress has been made in working out usable methods of herbicide treatment for different areas and species, and for utilizing new chemicals that are more effective or more selective in their action.

The tree injector may help meet the need for more convenient and less expensive means of applying herbicides to individual trees. A 44-pound ahg (pounds of acid per hundred gallons) mixture of 2,4,5-T in diesel oil applied with an injector to pole-size bitter pecan and overcup oak in the Mississippi bottom lands gave satisfactory kills. On the Sam Houston National Forest in Texas, 40 pounds ahg of 2,4,5-T in diesel oil gave satisfactory kills of sweetgum, post oak, blackjack oak, and southern red oak. A 20-pound solution gave a satisfactory kill of oaks but only a 54 percent top kill of sweetgum. The size of tree did not affect top kill but small trees sprouted more than large trees. In the rugged timber-growing country of eastern Tennessee it was found that a reasonably good estimate of man-hours, exclusive of supervision and travel to and from work area, required to treat a given number of trees could be had by multiplying the sum of the diameters of the trees by 0.0023 and adding 0.49. The amount of solution required could be estimated by multiplying the sum of the diameters by 0.0014. For example, in an 8-hour day, a man can treat trees aggregating about 3300 inches in diameter, and he will use about 4.5 gallons of solution. This information will be useful to forest managers in planning and scheduling their stand improvement work.

In the sandhills of northwest Florida, 35 combinations of different formulations and dosages of 2,4,-D; 2,4,5-T; 2-(2,4,5-TP); 2-(2,4-DP); 4-(2,4-DB); and 2,3,6-TBA were tried on turkey oak, sand post oak, bluejack oak, and sawpalmetto. The chemicals were applied in June from a helicopter at rates of 0.5 to 3.0 pounds of acid equivalent per acre in concentrations varying from 16.67 to 100 ahg in an oil-water carrier. A total volume of 3 gallons of diluted mixture per acre was applied from a height of 50 to 80 feet at a flying speed of about 40 miles per hour. None of the 35 treatments controlled the scrub trees to the extent required for satisfactory establishment of pine. These treatments also did not control the grass which is a serious competitor of young pine seedlings. Apparently some special treatments will have to be developed to expedite the conversion of these stands to pine.

Japanese honeysuckle in New Jersey can be killed with annual sprays of 2,4-D or amitrole applied in June for 3 years. However, periodic follow-up treatments are necessary to prevent re-establishment from seed. These results provide a much needed means for controlling Japanese honeysuckle.

Sawpalmetto, a plant that interferes with natural regeneration of pine in Florida, can be killed with low-volatile 2,4,5-T. A concentration of 3.5 pounds ahg was the most satisfactory. In contrast to the results with hardwood trees, applications in June were not as effective as those in January to April.

Bigleaf maple is considered an undesirable species in the Douglas-fir region in western Oregon and Washington. Although it shows strong resistance to most herbicides, good control was achieved by basal and stem application of 2-(2,4,5-TP) ester in oil. Unlike many other species, it is more sensitive to basal application than to application in frills. Careful application and occasional follow-up treatments should provide lasting control.

Of some 175 tree species growing on the Luquillo Experimental Forest in Puerto Rico, only about 27 are considered of potentially high commercial value at the present time. The removal of the undesirable trees to make room for these better trees constitutes an important problem in managing these forests. In a study started in 1956, it was found that 21 pounds ahg of a low-volatile 2,4,5-T ester in diesel oil applied in frills was effective in controlling most of the undesirable species. Better methods are still needed for certain refractory species, particularly those with highly fluted or multiple stems.

Results are now available from a comprehensive study in the Missouri Ozarks designed to evaluate some of the more promising chemical methods of killing hardwood trees which had given variable results in past research. The study included 14,000 trees involving 640 combinations of species, tree

sizes, herbicides, concentrations, carriers, and methods of application during 3 seasons of the year. Although the results of this study are quite variable they do provide good bases for selecting effective and economical treatments for different sized blackjack, post, black, and white oaks. For example, 50 pounds of 2,4,5-T ahg applied in low frills in June averaged over 80 percent kill for each species. But for some species-size combinations, other treatments with less expensive chemicals were more effective. In general, June treatments gave best root kills, and small trees were easier to kill than large trees. The author concludes that the choice of the proper treatment for a particular tree-killing job depends on species and size of tree, the objectives, and the cost and availability of labor at various seasons of the year.

A summary type publication on the use of herbicides for killing woody plants to release pine and other conifers in the Lake States is available. It contains brief discussions of the principal types of release needed and how they are accomplished, the types of herbicides used and the techniques of application suitable for various kinds and conditions of the competing trees and brush, and the relative effectiveness and average costs of various treatments.

Control of roadside brush is a time-consuming and costly operation for the Forest Service and other agencies concerned with roadside maintenance. On the basis of studies carried out in 1951-55, selective spraying with 2,4,5-T in oil has been adopted as standard practice on national forest roads in the northeast. U. S. Forest Service Region 7 has changed over from annual mowing to chemical control of roadside brush on all its national forests. Fire control pumper units are converted as needed into power sprayers at little cost. Experience to date indicates that most roadsides will stand 5 years or longer between treatments. Costs for chemical control are averaging about 40 percent less than costs for annual mowing.

The resistance of conifers, particularly conifer seedlings in the West, is becoming more important as more new chemicals are being used to release a wider variety of species. In Coastal Oregon, P.G.B.E., a butyl ether ester of 2,4,5-T, the recommended spray for killing salmonberry, did not seriously damage intermingled Sitka spruce and western hemlock seedlings. The resistance of these seedlings to 29 other combinations of chemical formulations and dosages was evaluated in this study and the results published.

In southwestern Oregon, foliage sprays of 2,4-D and 2,4,5-T caused little damage to Douglas-fir, particularly in a water carrier. Satisfactory chemical release of sugar pine and ponderosa pine is still dependent on finding a more selective herbicide.

In south Alabama, young longleaf pines overtopped by scrub hardwoods were not seriously damaged by any of three formulations of 2,4,5-T applied from a helicopter in sufficient amounts to result in a satisfactory release of the pines. The seedlings were equally resistant to the three formulations (2 to 6 percent mortality), but butoxy ethanol ester 2,4,5-T gave best kill of the hardwoods.

The antibiotic cycloheximide, or Actidione in the trade, is known to be effective against the fungus causing blister rust in white pine. But its toxicity to the fungi associated in the necessary mycorrhizal development of the pine was not known. It could have been possible that treatment to destroy the disease organism would also have resulted in destruction of the mycorrhizal organisms. In this study various mycorrhizae-forming fungi growing in sterile culture were treated with cycloheximide over a range of concentrations to determine toxicity levels. Also white pines growing with a complement of mycorrhizae were treated with cycloheximide in fuel oil, applied as a basal spray. Most of the fungi growing in sterile culture were inhibited by a concentration of 10 ppm. However, when applied to the stem, the chemical apparently was not translocated to the roots in amounts great enough to inhibit the fungal partners of the mycorrhizae. The results of this study suggest that use of the chemical for blister rust control will not upset the necessary mycorrhizal development.

6. Animal Damage to Forest Trees

When spruce-fir stands are cut, balsam fir often predominates in the subsequent regeneration. In a study to determine reason for this, white spruce and balsam fir seed were exposed over a 5-week period during fall in feeders designed to keep out birds and large animals. The small mammals showed a strong preference for spruce seed, taking fir seed only when the supply of spruce seed was exhausted. On two 1-acre plots, red-backed voles and deer mice consumed or stored about 26 pounds of spruce seed and 1 pound of fir seed in the 5-week period. These results indicate that small mammal depredations may be an important factor in contributing to the low ratio of spruce to fir seedlings that develop after cutting.

Deer and rabbit damage to young plantings of loblolly pine is common and sometimes severe. Four repellent formulations were applied to loblolly pine seedlings by dipping and spraying just before planting in 2 successive years. Efficacy against rabbits was not determined because of a decline in the local rabbit population during those years. All treatments appreciably reduced deer damage but some chemicals reduced seedling survival 10 to 15 percent. A commercial formulation of tetramethyl thiuram disulfide called Tat-Go is tentatively recommended; it did not injure seedlings and was as effective against deer as the other tested formulations.

Deer browsing ranks as one of the major problems in the regeneration of hardwood stands in Pennsylvania. In a seven-year exclosure study in oak-maple stands, aspen was completely eliminated from the open check plots and the stocking and growth of oaks, red maple, and other hardwoods were markedly reduced. This happened despite the presence of considerable browse in the area from a browse cutting. These results demonstrated once again that an abundant deer population may greatly reduce or completely prevent the regeneration of desired hardwood species.

Many small mammals hinder natural and artificial reforestation. A report from the Pacific Southwest Station describes studies of the populations of several common rodents in three forest types, ponderosa pine, lodgepole pine and red and white fir. In all, 12 species of rodents were discovered in the study areas. Various species of deer mice, chipmunks, and ground squirrels were most abundant in open stands of ponderosa pine; pine squirrels predominated in lodgepole pine, and deer mice were the most frequent of any of the rodents in the true fir type. Such information, which leads to a better basic understanding of the populations in different forest types, will help in anticipating what control or preventive measures may be needed.

Heavy deer populations are always a serious threat to young trees developing on cut-over areas. During tree-planting studies in clear-cut areas of the Douglas-fir type, browsing by Columbian black-tailed deer in California was recorded over a 6-year period. Damage to conifer seedlings varied from place to place and appeared to be related inversely to the amount of preferred browse plants growing on an area. Browsing, though generally not fatal to conifer seedlings, seriously reduced height growth when repeated year after year. For example, in a 6-year-old plantation where browse was sparce, planted trees were set back an amount equivalent to 3.6 years' height growth.

Yellow-poplar, one of the species especially palatable to white-tailed deer, is difficult to regenerate in areas where deer are abundant. On the Pisgah National Forest, overwintering deer congregate in coves and on lower slopes, which are also the more important timber-producing sites. A comparative study of clear-cut and partially cut stands of typical mountain hardwoods showed that there was more browse produced and that there was more browsing in the clear-cut area. However, enough trees escaped browsing for satisfactory regeneration. Two years after cutting there were nearly twice as many single stem sprouts and seedlings on the clear-cut area as on the partially cut area. Ten years after cutting the clear-cut area had three times as many seedlings and the new stand contained a significantly higher proportion of yellow-poplar, a favored browse species. Apparently, yellow-poplar can be reproduced successfully on clear-cut areas big enough to produce more browse than the deer can consume. Results of the study lend credence to the concept that timber and

wildlife resources can be managed simultaneously to the mutual advantage of both.

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B. MENSURATION

Problem

Intensive management of the forest types of the United States requires improved measurement of volume and more reliable predictions of future growth, yield, and quality of forest products. Productivity of forests both in quality and quantity varies markedly according to stand density as well as by site quality, tree age, and species composition. Optimum stand conditions for particular management objectives need to be determined for the many combinations of timber types, sites, and conditions found in American forests. Important forest regulation problems involving levels of growing stock and rotation lengths must be solved to guide wise management of large timber holdings.

Program

A continuing program of studies is conducted at all the Stations, often in cooperation with industries, other private landowners, State forestry agencies, and forestry schools. Special attention is being given to research in the growth and yield of managed forests and juvenile forest stands. Research is also concerned with mathematical techniques and forestry tools that will make for greater precision and efficiency in practical forest management operations and in forest research. A pioneering research unit at Berkeley, California, established in 1961, is studying

basic mensurational problems. Nationwide, approximately 10 man-years of Federal scientific effort is devoted to this work annually.

Progress

1. Growth of Residual Trees and Stands

Sycamore stands in the Piedmont are generally unmanaged and little is known of their response to cutting. A recently completed exploratory thinning indicates that degrade from epicormic branching may be related to the residual density after thinning. Before the cutting, most sycamores were free of epicormic branches for the first 25 feet. After the thinning, epicormic branching was serious only at basal areas of 80 square feet and less, as shown in the following tabulation:

Residual basal area per acre (Square feet)	Epicormic branches per tree (Number)
33	15
58	14
80	4
101	2
118	0
154	0

Ninety plot measurements of unmanaged slash pine stands in south Florida provided the basic data for developing a yield equation. The predicting equation which accounted for 90.5 percent of the variation about the mean can be stated as:

$$\text{Log } \hat{Y}_1 = 3.70240 - 37.861(\frac{1}{A}) + 0.388_28(\frac{SI}{A}) + 0.337(\frac{SDI}{A})$$

where $\text{Log } \hat{Y}_1$ = logarithm of yield in cubic feet outside bark for trees 4.5 inches d.b.h. and larger to a minimum top diameter limit of 3.5 inches inside bark.

A = average stand age in years
SI = site index at age 25
SDI = stand density index
b with subscripts - coefficients derived from the data

New site index curves and volume tables were constructed during the course of the study and reported in the paper. In addition, tabular yield values converted to board-foot volume and mean annual growth in cubic feet are given as well as average stand diameter tables.

A study based upon 161 plots in 51 counties in Maryland, Virginia, North Carolina, and South Carolina, produced yield estimates for even-aged Virginia pine from 20 to 60 years in age with varying densities and percent composition of Virginia pine. The yield equation which accounted for 81 percent of the sample variation in merchantable cubic-foot yields can be expressed as follows:

Logarithm yield (merchantable volume outside bark in cubic feet) =

$0.098451 - 0.030055\left(\frac{100}{\text{Age}}\right)^2 + 0.28752$ (log density) + 0.72820 (log composition) + 0.0236009 (site index).

A series of 153 plots were selected in 20- to 60-year-old stands of natural loblolly pine of a wide range in site index and density in Georgia, South Carolina, and Virginia. Approximately one-third of these plots were thinned to a range of residual densities at the time of plot establishment. These plots were rethinned and another one-third received their first thinning at the end of the first 5-year growth period. In the thinned stands, cubic-foot volume growth during the 5- to 10-year period was found to be significantly related to age, site, and density expressed as density percent and total basal area per acre. In the unthinned stands, cubic-foot growth was related only to age, site, and density percent. A progressive culmination of growth at higher levels of stocking as site increases is evident in all three expressions. The relatively flat growth curves in relation to density with a culmination point show that the forest manager has a wide range of stocking levels available without appreciable loss in merchantable cubic-foot growth.

Thirty-two permanent sample plots were established between 1913 and 1938 on the Whitman, Malheur, Rogue River, and Deschutes National Forests in eastern and central Oregon to study results of various methods of selection cutting in old-growth ponderosa pine. The study has yielded a large amount of data on growth and mortality of residual stands and development of reproduction, all related to original stand conditions and method or degree of cutting. This is of considerable reference value to foresters who are planning the management of some 12 million acres of ponderosa pine forests in this region. During the most recent period of measurement, net sawtimber growth averaged about 100 board feet per acre per year, but ranged from a loss of 16 to a gain of 220 board feet per acre. Variations in growth were associated more with reserve stand structure (composition by Keen tree class and diameter class) and with spacing than with particular method of cutting or even with exact volume of reserve. Hence, the forester often has rather wide latitude as to percentage of cut. However, this study shows that he must still exercise skillful judgment as to character and spacing of reserve trees, or in selection of areas for either partial or clear cutting.

Very little research has been done in central Oregon on response of older stands of lodgepole pine to thinning. Now that this species is recognized as a good potential source of pulpwood and small saw logs, information on growth and yield of thinned stands is urgently required. An unmanaged stand of lodgepole pine on the Pringle Falls Experimental Forest in central Oregon responded remarkably well to thinning at the age of 55 years. Diameter growth was stimulated, mortality reduced, and stems grew more rapdily into merchantable size classes. Thinning to a spacing of 12 by 12 feet at age 55 produced higher yields and merchantable volumes at age 77 than thinning to a spacing of 16 by 16 feet. This study indicates that thinning some central Oregon lodgepole pine stands as old as 55 years will increase timber production.

To evaluate effects of different degrees of release on individual Douglas-fir trees, a study was started in 1952 in a 41-year-old, site IV stand. A remeasurement at the end of four growing seasons showed that dominants responded more quickly and positively to the removal of competing trees than codominants or intermediates. A remeasurement at the end of seven growing seasons substantiated this initial trend and added to our understanding of the reaction of trees to the removal of competitors.

A recent measurement of planted 31-year-old Douglas-fir in northwestern Washington showed yield to be markedly higher than that of natural stands. Increased increment of planted trees is attributed to more exact spacing, which permits less inhibited development of individual trees. Per acre yield obtained (4, 583 cubic feet) compares very closely with those of planted loblolly and slash pine in the South, but is less than obtained in Douglas-fir plantations in Great Britain. Two thinnings at ages 26 and 31 have demonstrated the feasibility of thinning as commercial practice.

A study was established in a 37-year-old Douglas-fir stand to investigate effects of three thinning regimes on increment. Thinning, ranging from light and frequent to heavy and infrequent, did not measurably affect gross increment during the following 6 years. Difference in increment per unit of growing stock between thinned and unthinned stands was greater for the second 3-year period, suggesting that redistribution of growth capacity to remaining trees was achieved following a short time-lag. While basal-area increment was influenced significantly only by residual basal area, cubic-volume increment was influenced significantly by both residual volume and site index.

Red alder, the most important hardwood in Oregon and Washington, comprises about 11-3/4 billion board feet and is two-thirds of the hardwood resource in the two-State region. Intensified industrial demand for the species has stimulated interest in its management and utilization. A Department of Agriculture bulletin summarizes significant developments in red alder silviculture, management, and utilization, since the last

published account in 1926. The information and guidelines made available are of interest to landowners, land managers, and foresters concerned with managing red alder in pure stands or in mixture, and to loggers, mill owners, and wood processors who are users or potential users of alder wood. This publication is particularly timely in view of recent technological advances in alder pulp and paper manufacture which now exceeds all other uses combined.

About 5 million acres of young-growth Douglas-fir in Oregon and Washington are ready for thinning. Commercial thinning of these stands is believed capable of adding 3-1/2 million cords, or 1-3/4 billion board feet, to the annual cut of the region without impairing existing stand productivity. In a recent report, the theory and practice of thinning are discussed as they apply particularly to Douglas-fir. Some suggestions are offered for determining the applicability of thinning. Some physical and economic factors influencing profit from thinning are listed, and methods of carrying out the thinning operation are summarized.

Timber types in the northern Rocky Mountain and Intermountain regions frequently tend to overstock. In addition, tree limbs in these regions persist on the trees, thus discounting wood quality. A careful evaluation of the opportunities, values, and costs of thinning indicated that if thinning is started early in the life of the stand, the ratio of cost to revenues will be greatest. For a $5- to $30-per acre thinning cost, harvest value yield can be increased $100 to $175 per acre on poor sites and $500 to $1,000 on good sites. These figures represent the maximum opportunity. Thinning in stands that have suffered from overcrowding would, of course, return less. A similar evaluation of the opportunities, values, and costs of pruning showed that if the present difference in wood price due to quality continues, pruning offers a substantial opportunity to increase value yield. This is particularly true if pruning effort is concentrated on the more valuable species growing on the better sites. If greater volume and value yields are to be achieved in timber stands of the northern Rocky Mountain and Intermountain regions, a substantial effort in thinning and pruning will be necessary.

Reliable, up-to-date growth information is basic to forest management planning on commercial holdings. Growth data are presented in a report from the Northeastern Station based upon a sample of about 200 plots established in the early 1950's as a cooperative study involving 10 land-holding companies and the Northeastern Station. Results indicate that growth considerably exceeds the rate of 1/10 to 2/10 cord per acre per year that had been widely accepted in the past. Gross growth in some stand classes approached 1 cord per acre per year. Tabular data on growth by various stand classes is presented, and procedures for estimating growth on properties comprising a number of stand classes are discussed.

As the remaining old-growth stands are cut, the importance of second-growth timber assumes greater importance. Long-term information on growth and development of second-growth stands is needed to ensure effective management. Data from 21 permanent cruise plots, established in the 1930's in unmanaged second-growth northern hardwoods in New Hampshire and remeasured about 25 years later, showed that all stands, regardless of initial stocking, are moving toward a typical uneven-aged stand structure and a predominance of tolerant species. Beech increased under low initial stocking and will maintain its gains for many years. Annual basal area production has been greatest where initial stocking was lowest; hence, differences in initial stocking are disappearing. Natural trends in these stands indicate that selection or group selection cutting should be suitable. However, if intolerant species are desired, some form of clear-, patch-, or shelterwood-cutting must be practiced.

Choice of a management program suited to the given objectives of a timberland owner must be based upon an overall appraisal of the program--including growth, quality, reproduction, stand structure, and species composition. Ten-year results on these varied management aspects for good sites in Appalachian hardwoods are presented in a publication from the Northeastern Station for four management programs: commercial clear-cutting, 16-inch diameter limit cut, extensive selection management, and intensive selection management. Each program was carried out on a 5-acre plot. Second cuts had been made on the two plots assigned to selection management. Growth on the diameter-limit and selection plots ranges from 424 to 524 board feet per acre per year with, as yet, no strong correlation with management intensity. Quality has been increased most under selection management; attainment of stand-structure goals is not expected in less than 30 years. Reproduction is abundant on all plots. Until more reliable information becomes available from long-term records on large areas, these results will provide preliminary guides to foresters and timberland owners on choosing a suitable management program.

Knowledge of the effect of different intensities of cutting on the volume and quality of residual timber is needed for the formulation of cutting practices. An old-growth northern hardwood stand in Upper Michigan cut to progressively lower residual stocking levels showed that although the proportionate volume of timber in log grades 1 to 3 was almost identical for levels of 50, 70, and 90 square feet, the net yield in board feet per square foot of residual stocking was highest at 70 square feet. This gives additional evidence of the greater financial soundness of moderate partial cutting than clear cutting in this forest type.

Yield prediction is an essential step in the application of intensive forest management. Volume measurements taken on 46 tenth-acre plots during a soil-site study of old-field sweetgum in southern New Jersey have been used to develop a yield table and a yield-prediction equation. Factors in the equation are site index, stand age, and basal area. A somewhat less accurate equation, making use of only site index and age, also is presented.

These results will enable foresters and landowners to make fairly reliable yield predictions for sweetgum stands in southern New Jersey.

2. Forest Measurements

Point-sample cruising, which is more efficient than cruising using fixed radius plots, requires special conversion factors and ratio tables for expeditious use of the method. Tables adapted from several published sources were combined with plot measurement data to provide a unified set of tables for point-sampling in stands of ponderosa pine. For uniform stands, stand volume/basal area ratio tables have been prepared which simplify the field and office procedures. For irregular stands, tree volume/basal area ratio tables are presented, along with a suggested compilation procedure. The tables presented should be a considerable aid to foresters cruising ponderosa pine by the point sampling method.

The number of units that must be observed in a sample survey in order to estimate population values with a specified precision depends on the variability among the units. Information about variability can be obtained by taking a preliminary sample from the population, but this procedure may be costly. Often an estimate of the variability can be obtained from earlier surveys of the same or similar populations. If the units used in the previous survey differ in size from those to be used in the new sample, some adjustment must be made in the previously observed variability. A satisfactory procedure for making this adjustment is based on the assumption that the squared coefficient of variation $(CV)^2$ is inversely proportional to the square root of relative plot size (P). Thus, if the coefficient of variation (CV_1) for plots of size P_1 is known, the estimated coefficient of variation (CV_2) for plots of the same shape and orientation but different size (P_2) would be:

$$(CV_2)^2 = (CV_1)^2 \sqrt{\frac{P_1}{P_2}}$$

Stand volume equations were prepared for red pine and other species in Minnesota using the product of basal area and average dominant height. The cubic-foot and cordwood volume equations developed can be applied to several even-aged species, but board-foot equation apply only to red pine. These equations will greatly simplify the computation of stand volumes in the area to which they apply.

Volume tables that are more accurate and that apply to more specific species and conditions are being developed at several Stations. This past year volume tables for shortleaf pine in the Virginia-Carolina Piedmont, weight and volume tables for plantation-growth loblolly pine in the Southeast, cubic-foot volume tables for southern Appalachian white pine plantations, volume tables for Colorado aspen and spruce, pulpwood volume tables

for ponderosa pine in the Southwest, and board-foot volume tables for young-growth mixed-conifer timber in California are examples of progress made.

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C. FOREST GENETICS

Problem

The rapid acceleration of forest planting in the United States has set the stage for a tree improvement program of major proportions. Basic facts are needed concerning natural variation in forest trees and the heritability of characteristics that have biological or economic value. Strains or hybrids of timber trees having rapid growth, high quality, superior pest resistance must be developed as soon as feasible.

Program

A continuing, long-time program of basic and applied research involving the whole field of genetics as applied to forest trees, from cytogenetics to phenotypic selection and progeny testing, is under way. The program involves the study of variability within species with respect to growth rate, form, and adaptability to environment as a basis for superior tree selection. It is concerned with the heritability of characters such as disease and insect resistance, drought and cold resistance, wood quality factors, vigor, and other important morphological, physiological, and anatomical characters. Other aspects of the project include the investigation of crossability of various species, aimed breeding for specific characters, radiation-induced mutations, and factors affecting fertilization and flower induction. Basic genetic processes are investigated through cytogenetic studies of tree species. Also included is research on the identification, classification and distribution of species and hybrids of forest trees.

The program is carried on principally at three Institutes of Forest Genetics located at Placerville, California; Gulfport, Mississippi; and Rhinelander, Wisconsin; with additional work in Oregon, Idaho, Illinois, Vermont, Pennsylvania, Georgia, Florida, and Louisiana, involving cooperative research with numerous State agencies, private foundations, universities, and forest industries. In addition, research grants for basic research in genetics under the provisions of Public Law 480 are in force in Finland, Israel, India, Chile, and Brazil. The annual Federal scientific effort directed to this research by the Forest Service is about 25 man-years.

Progress

1. Variation and Selection

The importance of the proper source of seed for planting in any given area is more and more clearly shown as results appear from the South-Wide Pine Seed Source Study. In a Georgia plantation, there were substantial differences in the heights of longleaf pine trees from six different sources. The tallest source grew 2.8 feet more than the shortest in the first five growing seasons. There were also significant differences among the sources with respect to the number of seedlings which stayed in the grass stage. In the best source only 18 percent had not begun height growth by the fourth year, compared to 52 percent in the poorest source. In the same Georgia plantation, large differences have occurred also among loblolly pine trees from different sources. The best of nine sources was 19 percent taller in 5 years than the poorest. The sources varied with respect to incidence of fusiform rust also. After 5 years one source had no infection while two others had 10 percent infection.

Further evidence for clinal or ecotypic differences in forest trees was furnished by a study of white pine from different seed sources. Among white pine seedlings of 21 provenances grown in New Jersey, seedlings of southern origins grew for a longer period of time in the nursery, and to a greater height, than those of northern origins. Differences among provenances in (1) duration of growth, (2) total seasonal growth, and (3) percentage of growth completed by May 18 were highly significant, and these growth variables were highly correlated with latitude and length of growing season of place of seed origin.

In the South, slash pine may be an exception to hypothesis that there are differences related to the source of seed. In plantations established from seed collected in four States covering the extremes of the range of slash pine, after 22 years no significant differences existed in volume or incidence of fusiform rust. If confirmed by additional research, these findings, that there are no races of slash pine, will be of great importance as this is our most commonly planted species.

A difference in the root system may be one reason for observed racial variation in longleaf pine seedlings. Trees in eastern Georgia had much more fibrous root systems than those from trees in the western part of the range of longleaf pine. Root systems of seedlings from trees in the western part of the range tended to be tap-rooted. The fibrous root systems of the eastern trees probably represent an adaptation to moister soil conditions. If root type is a strongly inherited character, the results of this study give strong reasons for not using eastern seed sources in the drier, western part of the longleaf pine types.

The selection of outstanding seedlings in the nursery appears to be a means of identifying trees of outstanding genetic constitution. After four years of growth selected loblolly and slash pines were 16 and 19 percent taller, respectively, than the controls. For slash pine the best seedling per 146,000 was selected. For loblolly pine the rate was 1 per 44,000. A three-man selecting crew was able to look over a nursery of 30-50 million seedlings in a day in search of these superior seedlings, which will be used for breeding material.

For planting in lower Michigan, seed of jack pine should be collected in lower Michigan, according to recent results of a jack pine provenance study. Jack pine seed was collected in the range of the species from lower Michigan to northern Minnesota and planted in three areas in the Lower Peninsula of Michigan. Trees from the collections closest to the planting sites were the tallest after 5 years.

The importance of the old adage to use local seed source is emphasized by 20-year measurements of a seed source study in California. Trees from seed collected from elevations ranging from 345 to 6,500 feet for ponderosa pine and from 3,450 to 7,860 feet for Jeffrey pine were planted at elevations of 960, 2,730, and 5,650 feet. Although early indications were that the lower elevations sources were best, after 20 years the trees from sources close to the planting site are best. At the highest plantation, trees from the lower sources suffered greater breakage than the higher elevation sources. The progeny from high elevations were the most stocky but all sources developed more stocky at the high elevation planting site. Finally, the study pointed out the need for careful site index descriptions. Even though the trees were in each case ponderosa pine, site index measurements for a given locality varied depending on the source of the trees planted there.

The validity of criteria for selecting superior trees must be established by progeny tests, some of which may run for many years. Results after 15 years in a progeny study in California showed that two-year height in the nursery could be used to check performance. About 50 percent of the variation in 15-year height would be explained by the height at two years.

Furthermore, about 39 percent of the variation in 15-year heights was attributed to genetic control. Selection of seed trees on the basis of superior performance thus would result in faster-growing progeny.

Forest trees of the same species but from widely different sources often vary in their response to day length but the basic reason for this variation is not understood. One possibility is that some were more or less efficient photosynthetically. To gain an understanding of the reason, loblolly pine seedlings from sources in Florida and in Georgia were grown under photoperiods of 9.5 hours and 15 hours. The rates of photosynthesis and of respiration were determined by measuring the CO_2 exchange with a gas analyzer. Photoperiod was found to have no effect on the rate of photosynthesis but long photoperiods resulted in a greater amount of photosynthesis. Differences between races or clones appear to be the result of differences in the utilization of the photosynthate, resulting in greater growth, rather than in a difference in the rate of photosynthesis.

2. Tree Breeding

Some western white pine trees free of blister rust disease are able to transmit resistance to their progeny. A series of seedlings progenies from controlled and open pollinations with supposedly resistant and non-resistant trees were inoculated with the blister rust disease fungus. Four years afterwards only 5.3 percent of the seedlings from non-resistant trees survived compared to 18 percent from resistant parents. The best set of parents produced progeny whose survival rate was 49 percent. The strength of the heritability is such in the best of the parents that worthwhile gains in resistance can be expected for several generations by breeding for this character.

The anatomical and morphological structure of needles can be helpful in establishing the hybridity of pines. Nearly half of the contrasting needle characters of 42 pine hybrids were intermediate between those of the parents. In a few cases, however, the characteristic of one parent appeared, indicating an expression of dominance. In those hybrids where reciprocal crosses had been made, the characters were the same regardless of which species had been the pollen or seed parent. The study adds to the store of knowledge about the characters of pines and their hybrids.

Fiber length is an important characteristic of wood to be used for pulp. To determine the variability in fiber length in cottonwood, trees of various ages and diameters were sampled. The study showed that in any one tree the fibers near the bark were longer than those near the pith. Age and diameter of the tree accounted for about 50 percent of the variation in fiber length. The estimate of genetic variance was 30 percent. On this basis selection of trees for long fibers might result in an average maximum length of 2.0 mm in several generations compared to an average maximum of 1.28 mm in the sample trees.

Breeding for resistance to various insect pests of pine is an objective of the forest tree improvement program. At the Western Institute of Forest Genetics a rather large amount of variability was found among various hybrids and even members of the same species with respect to susceptibility to the pine reproduction weevil. Progeny of exotic parents were more susceptible to the weevil than those of native parents, and some individuals seemed to transmit a high degree of susceptibility to their progeny. The hybrids Pinus ponderosa X P. engelmannii, P. ponderosa X P. montezumae, and P. ponderosa X P. ponderosa var. arizonica, which are desirable because of their vigor, were found to be susceptible.

In order to create hybrids between two species of trees or races of trees with differences in time of flowering, it is necessary to store the pollen of one parent. Moreover, successful storage of pollen for a period of years permits researchers to use the same germ plasm year after year in their breeding studies. At the Western Institute of Forest Genetics, pollen of several pines stored for 15 years at 10 percent relative humidity and at 0°C. or 5°C. was still viable. Pollen of different species varied with respect to the storage conditions but the pollen of only one species failed to survive the 15-year period. In another study pollen stored at 5°C. and 10 percent relative humidity was still viable after 15 years but that stored at the same temperature and 25 percent relative humidity was not viable. Chemical analysis of the carbohydrate and organic acid content showed that the unviable pollen was lower in these substances than the viable pollen. Respiration rates at the higher humidity exhausted the supply of these energy sources. The study showed the need for low relative humidity for storage and the possibility of a chemical test for viability.

Because pollen often must be stored for nearly a year before it is used in controlled pollination, its viability may be questionable and must be checked. The usual procedure is to germinate the pollen grains, taking several days. In a study with the pollen of seven different pines, it was found that the vital stain, tetrazolium chloride, could be used to indicate viable pollen. The color reaction of the stain provided a measure of germination comparing very well with that obtained by the usual procedure.

The viability of seed of yellow-poplar is notoriously poor. Future tree breeding projects will be handicapped if some procedure is not developed to increase the viability. To determine the causes a detailed anatomical and cytological study was made during the period of pollination and fertilization. The results show that ineffective pollination is the cause of the low number of good seeds. The trees are usually self-incompatible even though the flowers are perfect. Moreover, some trees were not always compatible with other trees. Also pollination was effective for only a few days so that rainy weather might restrict the activity of bees and reduce the amount of cross pollination. The implications of this study are that compatible trees will have to be found in tree breeding projects but that there may be little possibility of selfing in controlled breeding.

Early flowering in forest trees is of great interest to foresters because it shortens the interval to produce seed in seed orchards and to span a generation in forest tree breeding. Scattered evidence of precocity in flowering is thus of great interest. In Mississippi female strobili were found on a pitch pine seedling that was only 12 months old from the time the seed was planted.

To provide a basis for possible manipulation of flowering in pine, the ontogeny and development of the ovulate strobili was followed in ponderosa pine. At Placerville, California the first evidence for strobilus formation appeared in the first two weeks of September. Strobili grew throughout the winter although the vegetative shoots were in a rest period. Treatments to induce flowering would have to be applied in advance of the time the buds are initiated, or in July or early August.

The propagation of superior trees for seed orchard establishment or in forest tree breeding is often a difficult process. The short shoots, or needle bundles, offer a great amount of plant material for vegetative reproduction. Trials of rooting them show that occasionally some do root and form shoots. To better understand the process, an anatomical study was made of the ontogeny of root and shoot. It was found that cambial cells and xylem and phloem parenchyma cells gave rise to callus tissue. Roots originated from finger-like protuberances of this callus. Excessive callus development impeded root development, however, the new shoot arose from a bud developed in the apical meristem. More research is in order to determine how to stimulate and control these developmental steps.

A major breakthrough has been made in understanding the cause of development of springwood and summerwood in trees. The relative amount of springwood and summerwood are important because of the relation to wood density, a character of importance in tree breeding. By a series of experiments with daylength, decapitation of the terminal bud, and the application of auxin to the decapitated stem, it was shown that large or small diameter cell formation is related to auxin production in the growing terminal. During the spring when the terminal is elongating, large-diameter, springwood cells are formed. When terminal growth ceases, small-diameter summerwood cells are formed. These processes could be reversed either by changing the daylength and stimulating growth or by changing the auxin supply exogenously. These observations fit in nicely with the theory of auxin action, namely that auxin maintains the plasticity of the cell wall. During high auxin production, the cell walls are plastic and expand, forming springwood. In summer with low auxin production, the cells do not expand.

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D. TIMBER-RELATED FOREST CROPS

Problem

In addition to the five major products of the forest (timber, forage, water, wildlife, and recreation) there are a number of timber-related forest crops, some of which are sources of important industries in different parts of the country. These products include naval stores, maple sap, Christmas trees, and a group of minor crops composed of edible, medicinal, and decorative materials. Some of these crops when integrated with timber production greatly enhance the total income of forest owners. These crops also provide a ready cash income which is not easily obtainable from periodic timber harvests. Many of the minor forest crops provide supplemental income to individuals in low-income areas and also provide opportunities for new industries. The research problem is to determine the potentialities of these timber-related forest crops and to develop the most efficient methods for their production.

Program

The present program of Forest Service research in timber-related crops includes a project in naval stores production and related tree improvement research at Olustee, Florida, a project in the production of maple products and related tree improvement research at Burlington, Vermont, and a small amount of research on Christmas tree production conducted as part of silvicultural projects in Michigan, North Carolina, and elsewhere.

Plans include initiation of a formal project on Christmas trees and other timber-related crops at Berea, Kentucky and intensification of the part-time effort on these problems in various silvicultural projects in the eastern United States and the Northwest. The naval stores research will include fundamental studies of the physiology of oleoresin flow and applied research on the improvement of gum extraction techniques and equipment. The extraction phase of the research will be coordinated with equipment development research in the forest engineering project of the Forest Service at Auburn, Alabama. The research on maple sap production involves studies of physiology of sap flow, maple orchard management, and the development of strains with higher sugar content and sap yield, all in cooperation with the University of Vermont. Research on Christmas tree production includes the development of types of trees better adapted

to Christmas tree use, as well as intensive cultural methods for diverse species, sites, and markets. Research on the miscellaneous timber-related crops such as nuts, greens, and drug plants will center on ways to increase the supplemental income to forest owners from this source.

Research on this project is closely coordinated with the naval stores and maple sugar processing of the southern and eastern Utilization Research and Development Divisions of the Agricultural Research Service. Some phases of the Christmas tree and maple sap production are studied by State agencies and universities often in cooperation with the Forest Service.

The annual Federal scientific effort devoted to this research by the Forest Service is 6 professional man-years. Of this number 3 are devoted to naval stores, 2 to sugar maple and 1 to all other timber-related forest crops.

Progress

1. Naval Stores Production

A manual for gum naval stores production was prepared to bring together in one place all the best and most modern methods of producing gum, and to describe the principal factors that affect gum flow. The methods and techniques are the result of 15 years of work at Lake City, Florida, by scientists who work closely with gum producers and timber owners throughout the naval stores belt. The manual covers such subjects as gum yield in relation to tree diameter, proper face widths, installation of spiral gutters with double-headed nails, use of the advance streak, turpentining and tree growth, bark chipping, treating the streak with acid, how to identify good acid treatment, how to raise tins, how to use the puller, how to use intensive chipping methods, and how to control insect attacks. The new manual is in great demand by all naval stores producers, foresters in the naval stores belt, and others interested in this industry.

Dry face of naval stores pines results in a permanent cessation of gum flow from a portion or all of the normally active part of the turpentine face. Many of these dry areas are attacked by insects and fungi, leading to stain and decay of the wood. The specific cause of dry face is not known, but drought is probably the most important predisposing factor. Short-crowned trees are more susceptible than others. Proper thinning to maintain tree vigor and crown development helps to reduce dry face. Two changes in gum extraction techniques during the last decade--the change from wood chipping to bark chipping with acid treatment, and the use of nailed instead of inserted gutters--cause a minimum of damage to the water conducting tissues of the tree during turpentining; the result is a more vigorous tree, with higher gum yields and less dry facing. Bark chipping alone has reduced the incidence of dry face by 50 percent.

Timber owners in the naval stores region have often wondered whether gum yields of trees in plantations would be comparable with those in wild stands because the trees are usually growing at closer spacings in plantations. In Georgia it was found over a 3-year period that gum yields in a 17-year-old plantation were comparable to those in wild stands when tree diameter and crown ratio were considered. Thus, yield tables for natural stands can be used for planted trees.

A problem common to all tree planting programs is how to relate initial spacing with individual tree growth and stand growth to obtain high returns on an area basis. Information about gum yields and tree growth in a Georgia plantation emphasize the returns from gum farming and wood production resulting from a wide spacing of 15 x 15 feet initial planting. In this example gross annual returns per acre per year were almost $19.00 for a 26-year period. It is pointed out that wide initial spacing permits individual trees to reach a size suitable for gum production and sawlogs at an early age.

Intensive management of southern pines and economic production of crude gum requires careful application of management practices to get the most gum from relatively low faces. In a study in Mississippi, within a face height limitation of 54 inches, biweekly chipping with 1-inch streaks and 60 percent acid produced 6 percent more gum over a 3-year period than weekly chipping to the same face height. These results will be of considerable value to naval stores producers faced with a shortage of chipping labor because they show high gum yields can be obtained with fewer streaks.

For longleaf pine the proportion of scrape in total season's yield is 20 to 24 percent; in slash pine 1 to 8 percent. These figures show that dippers should be instructed to punch the scrape from tins as early as August to prevent waste.

An understanding of the biochemical processes involved in the production of terpenes could lead to methods of stimulating the yield or to guides for selecting and breeding pines with increased yield. This study showed that both acetic acid and mevalonic acid were intermediates in the biosynthesis of alpha-pinene. These acids tagged with radioactive carbon were fed shoot tips of 2-year-old pine seedlings which were allowed to photosynthesize. Alpha-pinene extracted from the shoots contained radioactive carbon which came from the acetic acid in one trial and from mevalonic acid in another.

The chemical composition of the gum turpentines of the pines is of interest not only to the chemical and pharmaceutical industries but also to forest geneticists and botanists. In studies of the pines knowledge of the terpene constitution may provide important clues to relationships among speices.

Also knowledge of the chemical constituents may reveal possibilities of breeding for insect resistance in pines. A new bulletin brings together nearly 30 years of research and the information in about 50 publications. It lists the terpenes found in 101 pine species or varieties and discusses the significance of the common occurrences of the terpenes. This bulletin represents a major contribution to scientific knowledge.

2. Maple Sap Production

Breeding sugar maple trees for higher yields of sugar has been hampered by the lack of suitable propagation techniques. To overcome this handicap, a project on the rooting of maple cuttings was started at Burlington, Vermont. Cuttings were obtained from each of 46 trees one year and from 11 of the same trees the following year. Significant differences were found among the clonal lines with respect to the number of cuttings which rooted. Also the clones which rooted best the first year were not best the second year. Apparently the physiological condition of the trees differed at the two sampling times. In the mechanics of rooting cuttings, perlite or sawdust were found to be better rooting mediums than mixtures of sand and moss. Further research is in progress to find ways to improve the consistency of rooting.

3. Christmas Tree Culture

Corkbark fir (Abies lasiocarpa var. arizonica) may be a desirable species for Christmas tree growers in the Northwest. In a planting of the tree on the west slope of the Cascades in Oregon, both survival and growth were satisfactory. The trees had an attractive silvery color and should be equal or superior to local firs in consumer appeal.

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WORK AND LINE PROJECTS, Forest Management Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 to April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-f1	TREE AND FOREST CLASSIFICATION														
-1	Dendrology	x	x	x				x	x		x	x		x	I, C-2
-2	Tree ranges	x		x				x							
-3	Oleoresins of pine			x											I, D-1
-4	Silvicultural classification							x							
FS 1-f2	FOREST PHYSIOLOGY														
-1	Nutrient requirements		x				x	x	x		x			x	I, A-2-d
-2	Phenology		x	x		x	x	x	x	x	x	x			I, C-2
-3	Physiology of flowering			x			x		x	x					
-4	Vegetative propagation			x			x	x	x	x					I, D-2
-5	Effect of growth substances						x	x	x	x	x				I, C-2
-6	Light requirements		x	x				x	x	x	x				I, C-1, A-2-a
-7	Maple sap production								x						I, D-2

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
PSW - Pacific Southwest
INT - Intermountain
RM - Rocky Mountain
LS - Lake States
CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
WO - Washington - Beltsville

WORK AND LINE PROJECTS, Forest Management Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 to April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-f3	SILVICS														
-1	Environmental factors	x	x	x	x	x	x	x	x	x	x	x			I, A-1
-2	Silvicultural effects on soils		x					x		x	x	x			
-3	Silvics manual			x	x			x	x	x		x		x	
-4	Forest-wildlife relationships	x	x	x		x	x	x	x						I, A-6
FS 1-f4	FOREST GENETICS														
-1	Variation and selection		x	x	x	x	x	x	x	x	x	x			I, C-1
-2	Inheritance		x	x	x		x	x	x	x	x				I, C-2
-3	Tree breeding			x	x		x	x	x		x				I, C-2
-4	Genetics techniques			x			x	x	x		x				I, C-2
FS 1-f5	NATURAL REGENERATION														
-1	Seed production and dispersal	x	x	x	x	x	x	x	x	x	x				I, A-3-a
-2	Regeneration cuttings	x	x	x	x	x	x	x	x	x	x	x			I, A-3-b
-3	Aids to natural regeneration	x	x		x	x	x	x	x	x	x				I, A-3-c

[1] Research Locations

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PSW - Pacific Southwest
INT - Intermountain
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CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
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WORK AND LINE PROJECTS, Forest Management Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 to April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-f6	SEEDING AND PLANTING														
-1	Tree seed orchards		x	x	x		x	x		x					I
-2	Seed handling		x	x	x	x	x	x	x	x	x				I, A-2-a
-3	Direct seeding	x	x	x	x	x		x	x	x	x				I, A-2-b
-4	Nursery practice		x	x		x	x	x		x	x	x			
-5	Species adaptability	x	x	x		x	x	x	x	x	x	x			I, A-2-c
-6	Planting site preparation		x		x	x	x	x	x	x	x	x			I, A-2-d
-7	Planting methods			x	x	x	x	x	x	x	x				I, A-2-d
FS 1-f7	YIELD AND QUALITY														
-1	Growth of residual trees and stands	x	x	x	x	x	x	x	x	x	x				I, B-1
-2	Growing stock density	x	x	x	x	x	x	x	x	x	x	x			I, B-1
-3	Species composition		x		x	x	x	x	x		x				
-4	Stand structure				x		x	x	x	x					
-5	Prescribed fire for T. S. I.		x	x			x		x	x	x				
-6	Christmas tree culture				x										I, D-3
-7	Optimum stand conditions						x								

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WORK AND LINE PROJECTS, Forest Management Research DIVISION
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Reporting Year May 1, 1961 to April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-f8	STAND IMPROVEMENT METHODS														
-1	Pruning	x	x	x	x	x	x	x	x	x	x	x			I, A-5-a
-2	Silvicides for T. S. I.		x	x			x	x	x	x	x	x			I, A-5-b
-3	Mechanical methods for T. S. I.						x	x			x				
FS 1-f9	NAVAL STORES														
-1	Gum formation									x					I, D-1
-2	Gum flow stimulants									x					I, D-1
-3	Naval stores mechanization									x					I, D-1
-4	Naval stores culture									x					I, D-1
-5	Turpentining vs. timber quality									x					I, D-1

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Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-f10	FOREST MEASUREMENTS														
-1	Growth prediction methods	x	x	x		x		x	x			x			
-2	Management inventories	x			x	x									
-3	Volume estimation and converting factors	x				x	x	x	x	x		x			I, B-2
-4	Sample scaling		x								x				I, B-2
-5	Experimental design										x				I, B-2
-6	Overall stand productivity											x			
FS 1-f11	PILOT OPERATIONS														
-1	Compartment studies				x		x	x	x	x	x	x			I, A-4
-2	Naval stores and timber														
-3	Livestock, wildlife and timber								x	x					
-4	Watershed practices and timber				x										
-5	Silviculture and pest control					x			x	x					
-6	Farm forestry forties		x			x	x	x	x	x					
-7	Management units			x			x	x	x	x	x	x			1, A-4

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II. WATERSHED MANAGEMENT AND RECREATION RESEARCH

A. FOREST SOIL AND WATER RESEARCH

Problem

All of the major rivers of the United States have headwaters in forests, associated range lands or alpine regions. To derive the greatest benefits and protection from these headwater areas improved knowledge of the management of watersheds and streams is needed. More than half the waterflow of the country originates in such areas. Whether this water-flow is beneficial or harmful, is well-regulated, sustained flow of good quality or erratic and silt-laden will be contingent to a major degree upon how the headwater lands are managed. Generally accepted estimates of water use indicate a doubling in demand by 1980. The most logical place to look for additional supplies or improved timing of such supplies of the quality needed is in the headwaters. At the same time there are constantly increasing pressures to use these same lands for a variety of products and services in addition to their watershed function. Surveys of soils, which have been in progress on agricultural lands for many years, need to be tried on and adapted to mountainous forest lands. Soil surveys plus additional research are needed to determine how best to adjust these several uses to give the necessary protection and development to soil and water resources.

Program

This work includes basic and applied research into the relationships of soil, climate, vegetation, and water and the development of methods and techniques to: (1) rehabilitate forest and related rangeland watersheds that constitute sources of damaging flood runoff and sediment; (2) give adequate protection to soil and water resources while forest and related rangelands are being used for timber production, grazing of domestic livestock and big game, wildlife habitat, and forest recreation; (3) increase water yields or improve the timing of such yields under a variety of climatic, soil, geologic, vegetative and topographic conditions; (4) aid forest soil development and improvement; and (5) study the usefulness of soil surveys in the management of mountainous watershed lands. This research is cooperative with ten Federal agencies, twenty-one State, five municipal and sixteen private organizations.

Progress

1. Hydrologic and Erosional Processes

This research consists of a group of basic studies designed to increase understanding of climate, characteristics and hydrology of soils, the functioning of plants in relation to soils and water, and the factors involved in soil erosion and soil stabilization in the numerous forest and related watershed complexes.

a. Snow characteristics and behavior. In seeking methods of increasing snow deposition and prolonging snow melt, snow packs in uncut lodgepole pine areas, 5-, 10-, 20-acres clearcut blocks on north, south, east and west aspects, sampled from March 31 to May 22, 1961, averaged 2.5 inches greater in the clearcut areas than in the uncut. There was no significant relationship between the different sized clearcut blocks. Snow disappearance from the clearcut blocks preceded disappearance from the uncut areas by 10 to 14 days. The greatest response to clear cutting in blocks was on the eastern aspect where the clearcut blocks accumulated 3.2 inches more water equivalent than the uncut areas. In a somewhat similar study in New Hampshire, maximum snow water content amounted to 7.0 inches in a hardwood stand, 5.5 and 5.7 inches in red and white pine plantations, and 6.8 inches in an open field. Melt rates in inches per degree-day over 32° F., after accumulation on March 29, were 0.10 inch in the hardwoods, 0.04 and 0.05 inches in the red and white pine stands and 0.11 inch in the open field. This indicates that the snow cover remained twice as long under the pine as in the open.

b. Infiltration. Infiltration expresses the capacity of soils to take up water, and on rangelands being heavily grazed and on forest lands being logged or otherwise used by heavy equipment, this is a serious problem. A study conducted in central Utah on high altitude summer ranges indicates the bulk density of the surface inch of soil, live plant cover density, moisture content of the soil at 1-2 inch depth, air-dried weight of litter and the percentage of clay in the surface inch of soil are all highly correlated with 30-minute infiltration rates, with rainfall applied at 5 inches per hour. Further analysis shows that 49 percent of the variation in sediment eroded is accounted for by the product of percent bare soil and total plot runoff. Slope accounts for an additional 6 percent.

Frozen soils also affect infiltration and when rain falls or snow melts rapidly on such soils, serious flooding often results. In New Hampshire, concrete frost was found to be more prevalent under white and red pine plantations than under a northern hardwood stand. During the spring snow-melt period, frost had a maximum of 42 percent occurrence in the pines as compared to 20 percent in the hardwoods. However, it was observed that snow accumulation was greater under hardwoods and once the snowpack reached a depth of 18 or more inches, frost penetration was

restricted and snow temperatures remained at 31.5° F. At shallow snow depths of 6 and 12 inches, snow temperatures fell well below freezing.

c. Soil moisture storage. The amount of moisture stored in soils and the capacity of soils to store moisture are important in flood prevention, timing of water yield and streamflow, and the growth and production of trees and forage. Much of the research effort at the Coweeta Hydrologic Laboratory is designed to study the water movement through soils to provide guides for later evaluation of watershed treatments. On one gaged 7-acre watershed, a high correlation was found between soil moisture changes and daily streamflow rates. No consistent relationship was found between soil moisture and position on the slope in the surface 4 feet of soil; however, moisture content below the 4-foot depth did increase from ridge to cove. Differences in texture (silt and clay content) tended to mask the effect of slope position in the surface 4 feet of soil.

In a north Mississippi study, thinning 19-year-old shortleaf pine stands to 80 sq. ft. of basal area per acre reduced soil moisture loss during the first and second growing seasons after treatment, and increased the available soil moisture during droughts. Little change in diameter growth was apparent during the first summer after thinning. But during the second summer, pines on deep silt loam increased markedly, and those on clay loam and clay subsoils responded to a lesser degree. Prior to thinning most diameter growth occurred early in the growing season. After thinning, growth was accelerated throughout the growing season but growth was greatest during periods of plentiful soil moisture.

d. Evapotranspiration losses. Water losses from the soil due to evaporation and transpiration are of major significance in the water cycle and offer the best opportunities for water conservation and control. In agriculture, reductions in water loss have been reported by the application of hexadecanol to the soil under a stand of corn. Similarly, a granular form of this mono-molecular evaporation retardant was applied to calibrated high Sierra (California) forest sites in the summer of 1961, at three rates, 35, 130, and 680 pounds per acre. From red fir and natural brush sites, the indicated reduction in water losses ranged from 0.2 to 0.3 inch at four of five sites. At the fifth site, an increase in water loss of 0.4 inch was indicated. At sites where vegetation had been removed by dozing or in which bare ground occurred, reductions in evaporation at the treated sites were from 0.3 to 1.1 inches.

In a study of the processes of water use by plants, the internal water balance of several hardwoods was measured throughout the summer of 1961 at the Coweeta Hydrologic Laboratory in North Carolina. Leaves from trees growing both inside and outside plastic covered plots were sampled and soil and atmospheric stresses were related to variations in leaf-water deficit. Definite response of leaf-water deficit to soil moisture stress

between 0.3 and 2.0 atmospheres was produced within the plots. Leaf-water deficit was shown to depend jointly on soil and atmospheric moisture stress, with flowering dogwood (Cornus florida) being particularly responsive to both factors.

At the Coweeta Hydrologic Laboratory, soil moisture measurements in forested and cleared plots covered with plastic mulch, allowed separation of seasonal transpiration (ave. 14.83 inches) from drainage (ave. 3.26 inches). At the low moisture tension of 1.8 atmospheres soil texture had little relation to transpiration loss but did influence drainage. Drainage amounted to 2.45 inches in fine textured soils and 4.20 inches in sandy soils. Trees drew water from the entire 20-ft. depth of soil sampled, drawing in greatest quantity, earliest and most rapidly where roots were concentrated near the soil surface.

A Missouri soil drying study illustrated the effectiveness of litter in reducing evaporation. Total removal of hardwood trees and their accumulated litter reduced the evapotranspirational soil drying rate by one-third. Where the trees were removed but the litter left intact, the drying rate was reduced by two-thirds. Where the litter was removed and the trees left on the plot, drying rates were increased by 5 to 10 percent.

e. Percolation. Rainfall may infiltrate the surface layers of soil but unless it percolates to deeper depths, it soon shows up as streamflow and can become a major factor in the occurrence of floods. In a study of subsurface stormflow on a forested watershed in central Ohio, 50 to 90 percent of the artificially applied water falling on the surface flowed out from the subsurface layers within four to six hours. Rates and quantities of flow from individual depths and from the entire profile varied with storm intensity, duration, and antecedent moisture tension within the soil. Subsurface flow was most uniform from the 24 to 36 inch zone, ranging from 0.22 to 0.30 inches per hour, regardless of intensity or duration of the simulated storm. Flow was only slightly less uniform from the somewhat more permeable 16 to 24 inch zone but from the highly permeable upper 16 inches, flow was erratic varying with storm depth, intensity and antecedent hydraulic head. Since soil moisture tension was zero at the 16 inch depth, flow from depths lower than this was probably through a saturated medium. Where soil moisture tension was relatively high before and during runs, the greatest quantities of flow were recorded from the deeper zones, and little or no flow occurred from the intermediate depths. This indicates that the lowest zone overlying water-impeding strata must be wetted before flow will occur in the upper zones. Continuing work will relate sub-surface flow to physical soil properties and vegetative soil cover to provide a basis for possible manipulations of vegetation to control stormflow.

f. Soil detachment. Before soil erosion can be controlled it is necessary to determine and study the factors contributing to its occurrence. In a California study, soils from three parent materials (sandstone, basalt, and grano-diorite) and two cover conditions(grass and forest) were tested to determine the effect of vegetation and parent material upon six soil properties (texture, bulk density, organic matter, total porosity, PH, and mean aggregate size). Soil properties were not significantly influenced by these two vegetation types but parent materials were found to have significant influence on most soil properties. Over 40 percent of the variation in mean water stable size was explained by variation in percent organic matter, porosity, PH and bulk density.

In the Wasatch Mountains of Utah, a 0.1 acre plot of soil, kept clean of all vegetative cover for 12 years, demonstrates the effects of denudation upon runoff and erosion. Thirty-five erosion-producing storms increased bulk density of the surface soil from 0.57 to 1.48 grams per cubic centimeter; porosity was reduced by 35 percent; and surface stoniness increased to almost 20 percent by volume. On the uphill two-thirds of the plot, a relative increase in the sand component, a decrease in silt and a small change in clay occurred. Variations in proportionate removal of soil separates by storms are dependent upon storm amount, intensity and duration. A reduction in residual soil organic matter has occurred.

In a study of soil detachment in Nevada, some of the relationships of overland flow and exposed rock to erosion have been emphasized. Overland flow erodes and transports the detached soil while the presence of exposed rock accelerates the process by creating devious channels which tend to concentrate surface flows. The greater the ground area occupied by exposed rock (up to 23 percent) the more confined are the surface flows and the greater are soil losses. Snow cover, soil frost, and contour furrows reduce soil movement. As long as snow cover persists, it absorbs rain drop impact and reduces erosion in a manner similar to dense vegetation. Soil frost, before it melts, shows a strong anti-erosive influence by binding soil particles and increasing their resistance to this dislodgement. Shallow contour furrows trap soil displaced between furrows by holding back more overland flow.

g. Suspended sediment and deposition. Following destruction of the vegetative cover on the San Dimas (California) Experimental Forest by wildfire, erosion has increased drastically. Average suspended sediment concentration during the four major storms of the 1962 season ranged from 31,000 to 159,000 p.p.m., the concentration depending primarily on rainfall intensity. Streambed profile measurements of two canyons draining 7 to 9 hundred acre watersheds indicate an average aggradation of about 5 feet deposited on a uniform grade of 9 percent through the main channel. Stream gaging Stations in these streams have been buried under debris.

In West Virginia, erosion from a watershed clearcut of its forest cover, with poorly located and constructed skidroads, resulted in continuously high stream turbidities (up to 56,000 p.p.m.), a level considered to be detrimental to the growth of young trout. Light and moderate logging did not produce erosion in quantities harmful to trout. In Michigan, where stream erosion and stream stabilization are being studied on trout streams, measurement of soil loss from eroding stream banks showed an average loss of 12 inches from sand banks but only 1 inch from clay banks. This would indicate that different soils create different problems and require different forms of management for their stabilization.

h. Instrumentation. A part of the job of research is to develop instrumentation where none now exists. In Oregon, an instrument has been developed for measuring water movement through soils, which consists of a displacement flow meter and two porous plates. In operation, there is a continuous water column from the top plate surface through the meter to the lower plate surface. A small quantity of the water entering the upper plate moves through the meter to the lower plate and returns to the soil. Readings from the meter indicate rate of water flow through wet soil. An electrical circuit has been developed for an automatic drop-counter type flow meter.

A laboratory test of a precise electric thermometer for measurement of soil temperature has been completed for use in Oregon, and field trials have shown that bare surface soils are 10° to 12° F. warmer on an average autumn day and 14° to 15° colder at night than corresponding sites under forest litter and canopy. A cover of perennial grass reduces diurnal variation but gives less protection against temperature changes than a forest cover.

To record incoming radiation from the sun, a high output, 180 degree radiometer has been constructed and the potentiometric indicator modified for digital recording with an Eppley standard radiometer. The integration system offers many advantages for remote recording and will permit readings and print-out at one minute intervals with provision for accumulation of readings for daily, or longer, sample periods.

Because undisturbed soil samples are difficult to obtain, a portable hydraulic sampler has been devised in Mississippi. Steady pressures up to 5,000 pounds per square inch make it possible to sample such diverse materials as loose sands, heavy clays, and cemented parent material without the compression or shattering common with samplers driven into the soil by hammer. The sampler consists of a modified 2-ton bumper jack arranged to react against a steel beam held in place by anchors. Interchangeable sampling heads are provided - one tapered for use in soils where equipment is difficult to extract, the other for dry or compacted materials.

In Arkansas a gage has been developed to measure losses or accumulation of soil at a given place. A 25.5 inch bar with attached spirit level, is positioned over fixed reference stakes and stabilized by pins adjusted with screw clamps. Distance from the reference bar to the ground surface is read through 10 holes on 1.33 inch centers by use of a moveable graduated stainless steel rod. A set of 10 readings to 0.01 inch tolerance can be made by two men in 3-5 minutes.

i. Watershed condition and erosion hazard criteria. In the unglaciated area of southeastern Wisconsin, gully erosion in certain forested areas is common, but a survey of 40 completely forested drainages was made and in none of these was gully or channel erosion found. This indicates that concentrations of water from ridgetop farms passing through forested slopes at high velocities have been the cause of the gullies and indicate that gully erosion is not a feature of the natural landscape.

2. Prevention of Watershed Damage

There are many thousands of acres of forest and related lands that are still in good watershed condition. Increasing demand for use of these lands for timber harvesting, grazing, etc., requires that special attention be given to maintaining the present desirable condition of stable soils and controlled streamflow. For the most part this group of studies involves modifications of currently accepted land use practices to give special attention to the prevention of watershed damage.

a. Modified silvicultural and logging practices. On the Andrews Experimental Forest in Oregon, it is planned to separate the hydrologic effects of road construction from those due to logging and harvesting of the Douglas-fir timber. In one watershed, roads constructed in advance of logging caused clearing of 8 percent of the watershed area, but in three years since clearing there has been no influence on peak flows in the stream draining the watershed. However, low flows increased 19.3, 12.4, and 12.8 percent in 1959, 1960, and 1961, respectively. Stream measurements taken in a similar study in Idaho prior to logging and road layout showed geologic erosion of the granitic soils of three drainages, as indicated by sediment movement in the streams, to be 8.0, 9.0, and 13.1 tons per square mile. The higher amount shown for the third watershed reveals the effect of land slumping and channel erosion from a previously stable area, originating from high flows during a rain-on-snow flood event. Somewhat in contrast to this, it was found that during normal flow of streams draining undisturbed, old growth, Douglas-fir watersheds in Oregon,there was essentially no suspended sediment. Suspended sediment under these conditions is moved primarily during the rising stage of streamflow, at which time the concentration may readh 100 p.p.m., still an extremely low level of suspended material.

b. Road development guides. A study in the high mountains of Idaho was designed to provide a basis for planning the best spacing of logging road drainage structures to adequately control overland flow on road surfaces. Analyses show that six factors account for 81.6 percent of the variance in overland flow. The most important (33 percent) is a soil factor involving the ratio of soil particles greater than 2 mm. in diameter to water stable aggregates greater than 2mm. diameter. Almost equally important is the gradiant of the road surface, accounting for 31.6 percent of the variance. Other factors of importance are the direction of slope, ground cover on the cut slope, and steepness of the terrain upon which the road is located.

Other analyses from data taken on this area relate watershed and road characteristics to the distance sediment moves downslope from the shoulders of logging roads. Nine factors account for 95.4 percent of the variation in sediment movement distance, 45 percent of this is accounted for by distance from the shoulder to the first obstruction to waterflow. Again a soils factor, the ratio of water stable aggregates to soil particles in the silt and clay size classes is important, accounting for 26.2 percent of the variation. Other important factors are cross-drain interval, steepness of the upper slope, and some stability factors related to soil texture and soil compaction.

c. Operating forest pilot watersheds. In West Virginia, after a commercial clearcut of the timber stand, increases in storm discharge occurred in the growing season. Magnitude of the increase was variable, depending largely on antecedent conditions, and ranged up to about one-half area-inch in any one storm period. Logging disturbance to the forest floor was slight over most of the area so that the increase in stormflow appears to have been caused by a greater storage of soil moisture due to reduction in evapotranspiration, rather than to an increase in surface runoff. The timber harvests were made in 1957 and 1958 and their effects on streamflow are now rapidly diminishing. On the commercial clearcut watershed, increases in growing season discharge were 68 percent in 1959, 41 percent in 1960, but only 5 percent in 1961, of the increase measured immediately following logging.

3. Rehabilitation of Damaged Watersheds

This research is designed to develop techniques and management practices which will restore satisfactory surface flow and streamflow conditions and stabilize and improve soils on forest and range watersheds that have been damaged through past use.

a. Restoring depleted slopes. On eroded, compacted, New Mexico rangelands, soil pitting with a Calkins pitter reduced surface runoff 10 to 26 percent and reduced erosion 16 to 19 percent, measured from 9 separate rain storms. Soil ripping with an implement called the Jayhawker eliminated practically all of the surface runoff and erosion from 12 rain storms which occurred during the first year after treatment.

Experimental plantings of various species of trees, shrubs, grasses, and forbs for watershed rehabilitation and soil stabilization purposes were made on the eastern slope of the Colorado front range and judged for survival, growth, vigor and freedom from insect, disease, rodent and mechanical damage. Species showing the greatest promise were sand cherry, rose hybrid, silverberry, black mustard, hairy vetch, evergreen sweetclover, and yellow blossom sweetclover. These species will be further evaluated under a variety of growing conditions.

Observations of ground cover density, species composition, herbage production, infiltration, soil stability, soil bulk density, sediment production, and channel erosion in the Pleasant Creek, Utah, watershed were made six years after restoration by reseeding and compared with similar measurements made immediately prior to and 3 years after treatment. Overland flow floods were effectively controlled by the treatment and soil bulk density was lower on all reseeded areas six years after treatment, the greatest decrease occurring on the sites that were most compacted initially. Infiltration capacity has been increased on the poorer sites and vegetative cover improved. During the time the reseeded cover was becoming established, soils stability was less than it had been prior to treatment; however, six years after treatment the soil on most sites has regained its stability and on those sites with the greatest cover improvement the soil is much more stable than before treatment.

Studies on the Gallatin elk range in Montana have shown that ground cover density and soil bulk density were the two most important factors affecting soil movement from study plots subjected to six erosion-producing summer storms. Erosion increased as ground cover density decreased, the increase in erosion being rapidly accelerated where less than 70 percent of the ground surface was covered by plants and litter. As the intensity of rain storm increased, so did erosion. The increase in erosion accelerated rapidly when less than two-thirds of the ground was protected by vegetation or litter cover. Erosion also increased as bulk density of the soil increased, so it was concluded that the management objectives for maintaining or restoring soil stability on the Gallatin elk winter range are a ground cover of at least two-thirds and maximum soil bulk densities of no more than 1.04.

In north Mississippi only three of nine grass and legume species tested showed promise for revegetating and rebuilding badly eroded sites. Weeping lovegrass thrived both on loose sand and on compact silt loam. Switchgrass

and rescue grass were much more sensitive to changes in site. Common lespedeza, present only as an occasional plant at the outset, increased naturally because of the fertilizer added to the grass plantings and by the end of the test occupied from 25 to 90 percent of the plots which failed to produce seeded grass. A common native grass, little bluestem, was able to utilize moisture more efficiently at high tensions than was loblolly pine but the pine was more efficient than was sunflower. The critical season for planted loblolly pine seedlings on eroded areas was found to be the first growing season. In 10 years of test plantings in north Mississippi, 76 percent of all mortality occurred in the first year. This amounted to 19 percent of the total seedlings observed that died in the first season while only 6 percent of the seedlings died during the following two years.

b. Treatment of pilot watersheds. Sediment yield from burned chaparral watersheds near Roosevelt, Arizona, declined through the second post-fire year. Sediment averaged 6,300 tons per square mile compared to 39,000 tons per square mile in the first post-fire year. The sediment measured the second year at the outlets of the watershed appeared to be derived from channel bottom scouring rather than from the watershed slopes.

A depleted, eroding watershed in the Wasatch Mountains of Central Utah was revegetated in 1952, and since establishment of the new cover has not produced a measurable amount of sediment. A companion on untreated watersheds continues to yield sediments during snow melt and more intense summer thunderstorms. No change in ground cover density has occurred during the past five years.

Preliminary evaluation of the watershed emergency treatments applied to the San Dimas Experimental Forest following a wildfire in 1960 shows that planting of barley wattles on the contour are most effective in reducing storm flood peaks and suspended sediment.

4. Water Yield Improvement

This work is designed to ultimately provide methods of management to improve the quality, amount, rate, and timeliness of flow of water yielded from the major types of forest, range and subalpine lands.

a. Conversion of vegetative types. As part of a project to convert sagebrush areas to grass, a study was conducted near Laramie, Wyoming, to determine the rooting habits of high elevation sagebrush plants and how these rooting habits vary by aspect. Root systems of sagebrush plants growing on the ridge, in the bottom, east-facing and west-facing sites were excavated for study. No consistent differences in rooting habits between sites were noted. Root penetration ranged from 4-1/2 to 6 feet and the major concentration occurred near the soil surface. The depth

of the surface concentration corresponded to the depth of the "A" soil horizon. Penetration of roots to deeper zones was mainly through structural cracks or fissures in the soils.

In an experimental watershed in Arizona, 80 acres (1/3 of the watershed) were cleared of timber and planted to grass in 1958. Increase in water yield the first year was not significant but in the second year the water yield increased 2.0 inches over the 4.4 inches estimated as the pretreatment condition flow. In the water year 1960-61, the flow was 1.55 inches, an increase of 0.59 inches over the predicted 0.96 inch flow.

In Colorado, an experimental watershed was cut in 1955 utilizing a pattern of logging which alternately clearcut and left uncut blocks of trees. This removed 40 percent of the timber from a 714 acre, high elevation forest watershed. Each year water yields have averaged about 25 percent above that predicted for the uncut condition and have annually ranged from 2.1 to 4.2 area-inches greater during the five years.

5. Soil Improvement

Research in this area is directed toward finding techniques for speeding up soil development on deteriorated watersheds where top soil horizons have been washed away and infiltration, percolation and water storage capacities are low; and to improve the hydrologic conditions of wetland soils through manipulation and management of water levels.

On eroded Piedmont soils in South Carolina, plots in stands of old field pine were given additions of oak and hickory litter over the naturally occurring pine litter. By the 5th year, the gain in organic matter was significantly greater than on those plots having only pine litter. Gain in organic matter was essentially the same on plots receiving oak litter as on those receiving hickory litter.

Preliminary to studies of soil improvement in the northern forest wetlands areas, detailed data were obtained on one of the peat types in northern Minnesota, in regard to its water-holding capacity and moisture status at different levels above the water table. A satisfactory method of sampling peat soils in a long continuous core has been devised. In another study the important forest humus types of the northern forest region of the Lake States are being examined. Emphasis is being given to the "duff-mull" types and suitable criteria for field identification are being developed.

In the wetlands forest areas of the Southeast Coastal Plain, an analysis of problems has been completed. A survey of drainage practices and successes on test projects made by industry and universities will be made and results compiled and studied. This survey will help guide the next steps of research to be undertaken by the project.

6. Pilot Soil Surveys

A pilot program of soil surveys on the National Forests to determine their value in multiple-resource planning and management on a broad scale and in individual project planning and management on the ground, was initiated in Fiscal Year 1958, under the technical direction of the Division of Watershed Management Research. The pilot program has emphasized three objectives: (1) the survey itself, to identify and map the types of soils occurring on forest lands and to describe their characteristics; (2) the research needed to further describe the characteristics of soils and to interpret those characteristics in terms of the one or more uses to which the soils might be put; and (3) the training and development of men who can perform liaison duties with National Forest resource managers by properly interpreting soil survey information in terms of forest or range or watershed or recreation management or in engineering problems associated with wildland management. The surveys on the National Forests follow the national standards of the cooperative soil survey established in the Department of Agriculture for classification and mapping of soils and is closely coordinated with soil survey activities conducted by the Soil Conservation Service outside the National Forests.

During the pilot area phase, surveys have been made on 28 areas in all administrative regions of the Forest Service, including Alaska. Field work is complete on 16 of these areas and technical reports are in various stages of completion. Technical soil survey reports have been completed and published by the U. S. D. A. for two areas. These reports include: (1) background information on geology, climate, vegetation, land use, etc.; (2) all technical soils information and laboratory analyses for soils and engineering purposes; and (3) a section on the use and management of all the soils included in the survey.

Approximately 40 percent of the soil scientists' time has been given over to specific soil management services and training. In addition, five 2-week schools have been held to give representative field personnel a technical refresher soils course so they might make better use of soils information in their resource management operations. Furthermore, in an effort to reach all resource administrative personnel, a Handbook on Soils has been prepared and distributed to all Forest Service field offices.

Soils surveys on the National Forests have proven to be a useful management tool and a decision has been made to terminate the pilot phase and initiate full scale activities as a part of National Forest resource management. At the same time, technical leadership has been moved from the Division of Watershed Management Research to the Division of Watershed Management, NFRM.

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B. FOREST RECREATION RESEARCH

Problem

In 1940 recreation use on the National Forests amounted to 16 million visits; by 1961 annual visits had increased to 102 million. This great influx of public use has had its influence on the forest environment. The trampling of campers and picnickers has in some places worn away the protective forest floor and exposed tree roots, and the wear and tear on trees by recreationists has caused some species to die back or lose vigor--inviting insect and disease attack. Understory vegetation of the forest floor has likewise been subjected to wear, causing changes in species composition. In some heavily used areas the soil has become so compacted that plant life has died, leaving the sites with the appearance of swept pavement.

The rapid increase in recreation use during the last 15 years has generated many administrative problems. Little is known of the characteristics, demands, and economics of the recreationists--as individuals or as a large group. In order to plan and provide adequate recreation developments on forest lands, information is needed as to the amount and kind of use these lands are getting now and likely to have in the future. Where do these recreationists come from? How long and where will they stay in the forests? Will they travel far to alternative recreation areas? Will they pay the costs of recreation facilities provided through entrance and use fees?

A continuing increase in recreation use of forest lands is projected, but much research must be done to know the types of recreation facilities the public will demand before planning and development of future recreation complexes are undertaken. Furthermore, understanding the effects of human use on forest sites will strengthen recreation planning and action to assure protection and maintenance of forest recreation environments.

Program

Studies of the effects of human use on recreation sites in eastern United States are centered in North Carolina and Pennsylvania. In the west, applied and basic research on the ecology of National Forest campground sites is headquartered at Berkeley, California. Studies of projected forest recreation use are underway in Oregon, California, Utah, Minnesota, Pennsylvania, and North Carolina.

Progress

1. Effects of Recreation on Forest Environment

In 1961 a short-term study to determine the effects of fertilization on maintaining and rehabilitating sites worn by recreation use was completed at Warren, Pennsylvania. Results indicated that on lightly trampled vegetation, fertilization increases the volume of vegetation on off-trail plots. However, significant beneficial effects are not lasting and the effectiveness of the fertilizer decreased in statistical reliability progressively with the second and third remeasurements. On heavily trampled areas (on trail plots) fertilization had no apparent effect on increasing the volume of vegetation.

Related to this problem--recreation area managers have often indicated they could better preserve vegetation in areas of intensive public use if they were able to predict how well different types of low-growing vegetation would stand up under recreation activity. With this information they could design recreation areas in a way that would channel use on the more hardy types and protect delicate sites from destruction by heavy trampling.

As a practical aid for field use, a circular slide rule for estimating the tolerance and durability of low vegetation was developed. The slide rule is based on the following variables: (1) percentage of low-growing vegetation such as grasses and woody vines; (2) percentage of shade during the growing season; and (3) the weight of low vegetation in the absence of trampling. With proper modification, this measurement technique may have application in other regions.

Excessive soil compaction has been a problem at some recreation areas while others with similar heavy use report no difficulty. Preliminary study at Warren, Pennsylvania indicates that frost heaving loosens soil but the degree of breakup varies with soil texture. This may explain why compaction problems are not apparent in some localities, particularly where frost heaving is common.

In California, studies of the ecology of campgrounds in several National Forests were continued through 1961. The objectives are: (a) to determine the original natural conditions of forest sites where campgrounds have been located; (b) to determine changes to the site resulting from campground use; and (c) to determine and assess relative impact of factors responsible for changes occurring to the soils and vegetation on and adjacent to the campgrounds.

Preliminary results from this study point out that on many recreation areas the site is deteriorating faster than nature can rebuild it. Seventy percent of the campgrounds examined lacked the normal accumulation of dead twigs and leaves on the forest floor. Such litter is important in protecting the soil from compaction, aiding movement of water into the soil, and providing nutrients to the plant roots through the process of decay. On 60 percent of the campgrounds examined, so little litter was left that the trampled soil resembled paved surfaces. More detailed studies based on the findings of this inventory are continuing in 1962.

In studies in the southern Appalachians in North Carolina and Tennessee 280 campsites on National Forests were inventoried. Regression analysis indicates that site degradation resulting from mass recreation impacts is directly related to greater canopy coverage, and that between species differences in damage, or susceptibility to insects and diseases are consistently large.

The hardwood and conifer tree species in the southern Appalachians were ranked by ability to withstand the impacts of recreation use as gaged by disease infection, insect infestation, and decline. In these studies three shrubs in the heath family--rhododendron, mountain laurel, and azalea--were important understory components. All three appeared quite resistant to disease and insects, with azalea the most, and mountain laurel the least tolerant to heavy recreation use.

2. Forest Recreation Use

Research in forest recreation use breaks into two subgroups: (1) studies relating to measurement of numbers of recreationists and their travel patterns, and (2) studies of habits and preferences of forest recreation users.

Studies are underway in Oregon to determine which of six variations of unmanned registration stations is best for obtaining information on wilderness use. Study areas are the Three Sisters Wilderness Area, and the Mountain Lakes Wild Area.

Analysis of the data collected in 1961 showed that one third of all visits made to the study areas were by persons under 16 years old. Most persons walked in, with each group averaging between 3 to 4 individuals. Ninety-one percent of all visits were made by Oregonians or with Oregonian acquaintances. Of all visits, nearly 81 percent were made by persons who stayed only one day.

Other studies on the amount and type of recreation use were continued by the Southeastern Forest Experiment Station in cooperation with the Virginia Agricultural Experiment Station, Virginia Cooperative Wildlife Research Unit, and the Virginia Game Commission. The purpose of this work was to determine the best sampling procedures for measuring and predicting the nature of dispersed recreation use as experienced on the George Washington National Forest in Virginia. Estimates during the first 75 days of sampling in the summer of 1961 indicated approximately 220,000 man-hours of use for the 100 square-mile study area. During the 6-day big game season in November, sampling gave estimates of approximately 440,000 man-hours of use.

Work is underway in New Hampshire to devise a sampling system for estimating the number of people using unsupervised campgrounds. In a study on the White Mountain National Forest, visitors were counted on a sample number of campgrounds each evening during the entire summer. It was found possible to accurately estimate (standard error = 3.8 percent at 95 percent probability level) the total use of all unsupervised campgrounds for the season, from a relatively small sample.

During 1960 and 1961, data were collected for a study of distribution of recreation use in the Boundary Waters Canoe Area in the Superior National Forest.

Preliminary results of this study show:

1. The number of visits per year is increasing rapidly over each previous year.

2. Total man-days of use are less than previous estimates because the average length of stay is shorter. A large number of people stay on the area's fringes and enter it by day for fishing and sightseeing. (Similar patterns of use were discovered in the Pacific Northwest, as previously mentioned).

3. Visitors are highly concentrated in some places, while other attractive areas are seldom visited.

4. Except for a few of the heavily used access points, people do not seem to object to overcrowding.

The Pacific Southwest Forest and Range Experiment Station had two studies underway designed to develop techniques of measuring recreation use and perfecting sampling procedures. The first of these was a study of winter recreation on the Stanislaus National Forest at Dodge Ridge.

Six methods of measuring recreation use were compared for usefulness and accuracy. They are: (1) Cordon count of vehicles entering and leaving the area; (2) mechanical count during half-hour periods of vehicles entering and leaving the area; (3) time-lapse camera counts to record number of cars in the parking lot at 10-minute intervals; (4) automatic counts of rest room door openings to discover relationship between use of these facilities and use of the resort areas; (5) concessionaire records of ski-tow ticket and food sales, and ski rentals; and (6) Ranger's regular weekend count of vehicles in the parking lot.

The second study examined methods of measuring seasonlong use of camp and picnic areas in the recreation complex of the Summit Ranger District of the Stanislaus National Forest. The techniques developed employ computer programing as a means for rapid trend analysis.

Closely tied with measurement of public use is a determination of their preferences. A study of habits and preferences of recreationists on the Allegheny and Monongahela National Forests in Pennsylvania and West Virginia was completed, and analysis of the responses indicated that factors such as distance from home, education, health, occupation, income, age, and sex are related in significant ways to the recreation activities, desires, and attitudes of people.

Another study in Pennsylvania was started in 1961 to determine if preferences for camping, picnicking, swimming, and sanitation are related to certain sociological characteristics--age, sex, time of visit, duration of visit, camping experience, group relationships and family status.

Patterns of use of developed recreation facilities may serve as indicators of future demands of the camping and picnicking public. A study made at Chapman Dam State Park (Pennsylvania) and the White Mountain National Forest (New Hampshire and Maine) showed that the number of trees, type of ground cover, and presence of overhead tree cover definitely influence the amount of use various sites and facilities receive. This study was expanded in the summer of 1961 to examine visitor preferences for campsites on eight unsupervised campgrounds on the White Mountain National Forest.

Through the years the frequent occurrence of offensive odors in pit toilets has harried recreation area administrators and provoked complaints by the recreationists. During the year (1961) researchers at Warren developed a toilet with a flame actuated convection stack to draw the odors out of the pit and building. The device has proven effective and economical and is being installed in a number of recreation areas in the Northeast and Middle West.

Techniques for appraising the recreational qualities and potentials of forest areas have always presented problems in making inventories. One study being made by the Intermountain Forest and Range Experiment Station is aimed at developing guides to aid the forest manager in his recreation inventory. Experiments on the North Slope area of the Uinta Mountains in Utah show that aerial photos and field sampling techniques can greatly simplify the task of inventorying lakes and streams. This study is aimed at developing a technique to compare the recreation fishing potentials of various areas within the forest.

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WORK AND LINE PROJECTS, Watershed Management & Recreation Research DIVISION
FOREST SERVICE, U. S. D. A.
Reporting Year May 1961 - April 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-w1	HYDROLOGIC PROCESSES														
-1	Gross Precipitation Characteristics			x	x	x		x							
-2	Snow Characteristics and Behavior		x	x	x	x			x						II, A-1-a
-3	Interception of Precipt. by Vegetation		x	x		x			x						
-4	Overland Flow			x					x						
-5	Infiltration of Water into Soil			x	x	x			x						II, A-1-b
-6	Soil Moisture Storage	x	x	x	x	x	x		x	x	x				II, A-1-c
-7	Evapotranspiration Losses	x	x	x	x	x	x		x	x	x				II, A-1-d
-8	Percolation	x													II, A-1-e
FS 1-w2	EROSIONAL PROCESSES														
-1	Process of Soil Detachment		x	x	x										II, A-1-f
-2	Sediments Transport and Deposition	x	x	x	x	x	x		x						II, A-1-g
FS 1-w3	IMPROVED WATERSHED MEASUREMENTS														
-1	Watershed Instrumentation	x	x	x	x	x	x	x	x	x	x				II, A-1-h
-2	Watershed Prediction Methods		x	x	x		x		x	x					
-3	Watershed Experimental Methods														
FS 1-w4	WATERSHED CLASSIFICATION METHODS														
-1	Watershed Condition Criteria			x		x	x			x	x				II, A-1-i
-2	Erosion Hazard Criteria					x	x								II, A-1-i
-3	Soil Survey Procedures								x						II, A-6

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
PSW - Pacific Southwest
INT - Intermountain
RM - Rocky Mountain
LS - Lake States
CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
WO - Washington - Beltsville

WORK AND LINE PROJECTS, Watershed Management and Recreation Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1961 - April 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-w5	WATERSHED DAMAGE PREVENTION METHODS														
-1	Modified Silvicultural Practices		x					x			x				II, A-2-a
-2	Modified Logging Methods	x	x		x	x									II, A-2-a
-3	Road Development Guides		x		x										II, A-2-b
-4	Modified Grazing Practices		x			x									
-5	Modified Range Improvements										x				
-6	Modified Fire Control										x				II, A-2-c
-7	Modified Strip Mining							x							
-8	Operating Forest Pilot Watersheds		x				x								
-9	Grazing Pilot Watersheds														
-10	Modified Drainage Practices						x			x					II, A-5
FS 1-w6	WATERSHED REHABILITATION METHODS														
-1	Restoring Depleted Slopes		x			x	x				x				II, A-3-a
-2	Gully Control Methods				x	x	x			x	x				
-3	Repairing Construction Disturbance		x		x				x						
-4	Rehabilitation Treatment Pilot Watersheds			x	x	x			x						II, A-3-b
-5	Channel Stabilization Methods						x								
FS 1-w7	WATER YIELD IMPROVEMENT METHODS														
-1	Phreatophyte Control					x									
-2	Type Conversion on Drained Slopes			x	x	x			x	x					II, A-4-a
-3	Thinning Forest Cover-Rainfall Areas					x			x						II, A-4-a
-4	Cutting Snowpack Timber			x	x				x						II, A-4-a
-5	Alpine Snow Control				x	x									
-6	Improving Water Yields-Pilot Watersheds			x		x				x					

[1] Research Locations

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WO - Washington - Beltsville

WORK AND LINE PROJECTS, Watershed Management & Recreation Research DIVISION
FOREST SERVICE, U. S. D. A.
Reporting Year May 1961 - April 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-r7	BIOLOGICAL AND PHYSICAL FACTORS			x					x	x					II, B-1
FS 1-r8	RECREATIONAL USE FACTORS		x	x	x		x		x	x					II, B-2

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
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INT - Intermountain
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III. RANGE AND WILDLIFE HABITAT RESEARCH

A. RANGE MANAGEMENT

Problem

Present forage production on vast areas of rangeland is far below the potential and falls short of meeting the demands for livestock and game grazing. Many areas, particularly in the western mountains, have been damaged to the point that watershed values are seriously impaired. Livestock grazing can also have serious impacts on production of timber and wildlife; consequently, there is urgent need for developing range management practices that will improve and efficiently utilize the resource.

Specific phases of the problem are: (1) to determine characteristics and requirements of range vegetation, classify range condition and trend, and develop improved vegetation measurement techniques and range inventory procedures, (2) determine optimum management systems and intensities of grazing to obtain maximum production and efficient use of forage on the various types of rangeland, (3) determining effects of fire on vegetation and soils and developing practical guides for its use in controlling undesirable plants, increasing forage production, and improving quality, and (4) determining the identity and ecological relations of rodents and other range pests as a basis for their control.

Program

This is a continuing, long-term program of both basic and applied research at numerous locations in the various range plant communities of the West, Midwest, and South in cooperation with State colleges and universities, forestry and fish and game departments, and Agricultural Experiment Stations; as well as with the Smithsonian Institution, Bureau of Land Management, Bureau of Indian Affairs, Fish and Wildlife Service, Agricultural Research Service, numerous herbaria, private companies, and livestock associations or individual ranchers. Grazing management studies with cattle are conducted at Coarsegold, California; LaGrande, Oregon; Hammett, Idaho; Woodland Park, Colorado; Tucson, Arizona; Sheridan, Wyoming; Benmore, Utah; Albuquerque, New Mexico; Columbia, Missouri; Alexandria, Louisiana; Tifton, Georgia; and Ft. Myers, Florida, and with sheep at Albuquerque, New Mexico; Dubois, Idaho; Milford, Utah; and Ephraim, Utah. Methods of burning and ecological effects on various types of range vegetation are being studied at Dubois, Idaho; Flagstaff, Tempe, and Tucson, Arizona; Wenatchee, Washington; Glendora, California; Columbia, Missouri; and Tifton, Georgia. Present studies on range pests, particularly gophers; are centered in Colorado, Utah, and Nevada and are

attempting to ascertain the nature and extent of infestations and their influences on range vegetation and soil.

The Federal scientific effort involved in this research totals approximately 45 professional man-years. Of this amount 21.5 are devoted to range vegetation evaluation, 18.0 to livestock grazing practices, 3.5 to burning for range improvement, and 2.0 to range pest influences and control.

Progress

1. Range Vegetation Evaluation

a. Ecology and physiology. In northern Arizona 20 native species all contained chemicals that inhibited the growth of wheat seedling radicles. Water extracts of the grasses showed less inhibitory effect than those of forbs, shrubs, and trees; however, extracts of all four classes of plants reduced radicle growth more than 50 percent. Junipers (Juniperus spp.) showed inhibitory effects under field conditions, whereas grasses did not. Thus, the existence of a growth inhibitor in a plant extract does not necessarily mean that it has ecological importance.

A relict area in the central Oregon juniper zone was studied in which antelope bitterbrush (Purshia tridentata) and bearded bluebunch wheatgrass (Agropyron spicatum) dominate the plant community. Foliage cover of these species was approximately 9 and 6 percent, respectively. The soil in the area is a very shallow (8 inches) sandy loam Regosol of aeolian origin overlying a buried, stony, clay loam. This soil is extremely different from the strongly developed Brown loam in an immediately adjacent vegetation-soil system where big sagebrush dominates the shrub statum. These results emphasize the importance of simultaneous vegetation-soil investigations when classifying range units for evaluation of management practices.

Yield of grass is usually reduced by invasion of big sagebrush (Artemisia tridentata); however, a study at Benmore, Utah indicates that invasion by rubber rabbitbrush (Chrysothamnus nauseosus) may actually increase production of crested wheatgrass (Agropyron desertorum). A comparison of the root systems of sagebrush and rabbitbrush provides a partial answer for the differences in their effect on wheatgrass yields. Taproots of big sagebrush are frequently restricted by a calcareous hardpan or salt accumulation in the lower soil layers, whereas the taproots of rabbitbrush are but little affected. When sagebrush roots are restricted, numerous lateral roots develop in the upper soil layers where they utilize surface soil moisture. Crested wheatgrass apparently is not able to compete with sagebrush and barren "halos" develop at the perimeter of the shrub crowns. Poorly developed lateral roots of rubber rabbitbrush offer little competition to crested wheatgrass which grows profusely

under and adjacent to the shrubs. This unusual relation between an undesirable shrub and a grass is still under study.

Chemical analyses were completed to determine the seasonal fluctuation in carbohydrate reserves of bitterbrush (Purshia tridentata) in north central Washington. Tops and root systems were collected at each of the following growth stages: spring dormancy, full leaf, full flower, initial twig growth - early seed formation, seed maturity, cessation of growth, leaf fall, and winter dormancy. The percentages of total available carbohydrates in the various root and top strata all reflect pronounced seasonal fluctuation in the plant's food reserves, especially the roots. The period of lowest carbohydrate accumulation in bitterbrush tops occurred in May when the plant was in the full flower stage. The characteristic lag in depletion of root reserves was apparent in that the lowest level was not reached until seed maturity, approximately 6 weeks later. After the period of excessive energy demand there is a steady accumulation of reserves in tops and an extremely rapid buildup in the roots. Thereafter, a gradual decline in reserves takes place through the early winter months, presumably the result of consumption by respiratory processes.

Meter-square quadrats established on subalpine range in 1912-1913 on the Manti National Forest in Utah were recharted in 1959 and 1960. Important differences are apparent between grazed and protected areas. Infiltration is more rapid on areas protected from grazing than on grazed areas where annual trampling by sheep compacts the soil. In general, grasses predominate under grazing, and forbs are more abundant on the protected plots. There has been some increase of vegetation cover on both the grazed and ungrazed areas. It is most pronounced on the protected areas, but there are still areas that do not have adequate cover for soil stabilization. This slow rate of recovery is attributed to unfavorable microclimate and soil of low fertility and is in sharp contrast to that described below on Missouri glades.

In the Missouri Ozarks, the glades have been overused by livestock for many years and forage production has been greatly reduced. However, glade ranges recover very rapidly from heavy grazing use. In one exclosure herbage production increased from 400 lbs. (dry weight) per acre to 2,800 lbs.--a 600 percent increase--during 4 years of protection from livestock grazing.

Complete protection of native tall grass prairie in Iowa causes an excessive accumulation of litter which decreases vigor, growth rate, and yield of prairie vegetation. Burning following protection caused an increase in number and height of seedstalks of the grasses, faster vegetative growth during the early part of the season, and a slightly greater herbage yield. When organic matter was again allowed to accumulate, vigor, growth rate, and yield declined rapidly. However, where annual mowing and

hay removal prevented excessive accumulation of litter, vigor, growth rate, and yield decreased only slightly.

Autecological studies of saw palmetto (Serenoa repens) were continued in Georgia and Florida. Germination of seeds of this species occurred sporadically over a period of several months. In laboratory tests 85 percent germination was achieved in 200 days. Tests revealed that seed coats were of low permeability to oxygen. When embryos were exposed by removing the micropyle caps, germination began in 10 days, and 70 percent of the seeds germinated in 50 days. Similar results were obtained when seeds with intact coats were placed in high oxygen (80 percent) environment.

b. Plant identification. In the Pacific Northwest, a key based on leaf, bud, and twig characters was prepared to allow identification of shrubs at any season of the year and without reference to flowers or fruit. Also, for this same region, a plant symbol list was designed for use in automatic data processing. In Wyoming a key was prepared to allow identification of grasses in the Bighorn Mountains by vegetative characters. A bulletin on browse plants in the South was published to help land managers improve their knowledge of southern forage plants. The plant descriptions specify where species occur, normal growth habit, and tolerance to browsing. Collection and identification of range plants was continued at various locations in all Stations, and specimens were deposited in appropriate field herbaria and in Washington.

c. Forage values. Chemical analysis of forage samples obtained from native range at Tifton, Georgia, continue to point the need for supplements especially for cattle grazing unburned range. Crude protein of forage from the wiregrass type dropped from 8.8 percent in April to 5.3 percent in September. Comparable averages for samples from range burned the previous winter were 11.1 and 7.0 percent.

In Florida applications of rock phosphate on native range produced extremely favorable responses both in terms of forage production and animal use. Yields of total herbage increased dramatically. During the first year they were more than doubled on plots receiving 1 ton of rock phosphate per acre and more than tripled on plots receiving 2 tons per acre. Perhaps the most interesting response was the increase in desirable forage plants. Cattle eagerly sought out and closely grazed the abundant forage that grew on the fertilized plots. The study also affords a striking demonstration of saw palmetto (Serenoa repens) control from heavy grazing induced by fertilization.

Crude protein levels of grasses and sedges in the Black Hills of South Dakota declined steadily from June through October. For example, protein content of Kentucky bluegrass, (Poa pratensis) and roughleaf ricegrass (Oryzopsis asperifolia) dropped from between 12 and 18 percent in early June to 7 or 8 percent by mid-October. Phosphorus followed a similar downward trend through the season, but calcium remained about constant or increased as the plants matured. Plants growing on timbered range in partial shade contained significantly more crude fiber and less nitrogen-free-extract than plants in open meadows. These differences in composition probably contributed to the much higher livestock utilization of bluegrass growing in open meadows (57 percent) than that on adjacent timbered range (7 percent).

On forest ranges of the Missouri Ozarks, protein content of native grasses such as big bluestem (Andropogon gerardii), little bluestem (A. scoparius) and switchgrass (Panicum virgatum) falls below minimum requirements for cattle by mid-summer. But native legumes such as tick trefoil (Desmodium spp.) and bushclover (Lespedeza spp.) and other forbs such as black-eyed-susan (Rudbeckia hirta) remain high in protein until late summer. These species extend the time during which cattle can get their daily protein requirements from forest range. The phosphorus content is more than adequate during the early part of the growing season, but becomes deficient in late summer; calcium content is adequate all through the year.

d. Vegetation measurement and sampling. Various plotless methods for estimating plant density (number of plants per unit area) were evaluated in Colorado and Arizona. In Colorado, the angle-order-quadrant method in seeded stands of smooth brome (Bromus inermis) and intermediate wheatgrass (Agropyron intermedium) grazed at different intensities gave consistently higher values than did the list-transect method. In the plotless method, the distance to the third nearest neighbor was measured.

In another study in Arizona, the point-centered quarter method, the angle-order method, and actual plant counts were compared for estimating plant density. The point-centered quarter method gives accurate and efficient estimates of plant densities if the plants are randomly distributed. The angle-order method will give accurate density estimates in non-random distributions but is not efficient because of time required to make measurements. Plant counts in plots of proper size and shape appear to be the best way to estimate plant density.

In Oregon, studies to determine the optimum plot sizes for measuring species frequency show that plot sizes vary according to species, sites, and past grazing history. It was found that optimum plot sizes ranged from approximately 12 square inches for pinegrass on forested soils of the Tolo series to 80 square inches for bearded bluebunch wheatgrass (Agropyron spicatum) on the grassland soils of the Ukiah and Albee series.

Optimum plot size for Sandberg bluegrass (Poa secunda) and onespike danthonia (Danthonia unispicata) on specific sites was 41 square inches and for elk sedge (Carex geyeri), 55 square inches.

In Montana, a method for estimating browse utilization from numbers of twigs browsed was compared with measured utilization, using linear reduction of total annual growth of twigs. Based on 133 serviceberry (Amelanchier alnifolia) and 68 chokecherry (Prunus virginiana) shrubs on winter game range, correlation between percentage of twig numbers browsed and percentage of linear growth utilized was 0.8597 for serviceberry and 0.7839 for chokecherry.

In Idaho, twig diameter-length-weight relations of bitterbrush (Purshia tridentata) show promise for obtaining more reliable estimates of bitterbrush utilization and production. Studies using these twig measurements for 20 mature plants on each of two sites show that twig lengths and weights were highly correlated with twig diameters.

At Bend, Oregon, trials in two kinds of overstory, birchleaf mountain-mahogany (Cercocarpus betuloides) and western juniper (Juniperus occidentalis), show that the spherical densiometer provides precise and accurate estimates of canopy cover directly above a line. The difference between two operators measuring total crown intercept on six 50-foot transects under curlleaf mountain-mahogany was 0.9 percent. On eight transects under juniper, this difference was 0.7 percent.

Results from the California foothill annual type showed highly contagious distribution of nearly all species and groups. Therefore, the point-center-quarter technique is not well adapted for use in this annual type.

2. Livestock Grazing Practices

a. Native ranges. In the Bighorn Mountains of Wyoming, Idaho fescue plants maintained better vigor on sedimentary than on granitic soils. Even light grazing reduced the vigor of plants growing on granitic soils. As utilization of Idaho fescue increased above 40 to 45 percent, production not only decreased, but less desirable species began to increase. These changes were more pronounced on granitic than on sedimentary soils. It was concluded that management of the ranges studied should be based on not more than 40 to 45 percent utilization of Idaho fescue by weight. Under this use intensity, yearling steer gains averaged 2.2 pounds per day and the range was maintained or improved. Lighter rates of grazing result in higher gains per head per day but lower per acre gains. Heavier rates produce more gain per acre but less per day, also the range is damaged.

Over a six-year period, calves grazing under a seasonlong management system in the Blue Mountains of Oregon have gained materially more than those under a rotation-deferred system. This is unusual because many grazing experiments have demonstrated the superiority of rotation grazing for both cattle and vegetation. During the 1961 grazing season, however, calf weight gains were greatest on the rotation-defered pastures. It is not apparent whether such reversal of animal gains is the cumulative effect of several years treatment on the vegetation or whether it is merely the effect of the unusually dry weather of the 1961 season. At any rate these results indicate the need for studying grazing-vegetation-climatic relations over an extended period in order to produce conclusive results.

Cow and calf production on the Caloosa Experimental Range, Florida, continued to reflect effect of stocking rate after three years of study. Calf weaned weights for the 1958, 1959, and 1960 period averaged 256, 302, and 313 pounds, respectively, for the high, medium, and low stocking rates. In 1960, cow weights for the three stocking rates were 662 pounds, (high), 700 pounds (medium), and 776 pounds (low). No effects of rates of stocking on production of pineland threeawn (Aristida stricta) on fresh burns were apparent after three years. In 1960, however, considerably more herbage of choice species was available on low and medium rate pastures than on high rate pastures.

At Tucson, Arizona, three-year results show that greatest range improvement after mesquite (Prosopsis juliflora var. velutina) control on semi-desert range occurs from grazing when perennial grasses are dormant. Production of these species increased 70 percent when grazed only during the fall-winter-spring period, increased 35 percent on ranges grazed year-long, but did not increase at all on ranges grazed only in the spring-summer-fall period. At the same time, production increased 62 percent on areas underlain by a clayey subsoils, but only 23 percent on areas with a sandy subsoil. As indicated in Wyoming, soil differences must be considered when prescribing grazing management practices.

Blue Mountain, Oregon, weather conditions appeared to cause fluctuations in crude protein content of perennial vegetation. The seasonal decline in protein of principal forage producing species responded to the amount and seasonal distribution of mid-summer precipitation. Cattle weight gains over an eight-year period were also found to be associated with the amount and pattern of mid-summer precipitation. Seasonal forage quality and the resulting cattle weight gains were therefore closely related to soil moisture conditions. Spring precipitation usually provides sufficient moisture for production of an adequate forage crop. However, because of rapid soil moisture depletion during late spring, plants are dependent on additional summer precipitation for continued activity and retention of nutrient quality.

At O'Neals, California, unusually heavy winter precipitation strongly leached the annual-plant vegetation carried over from the 1961 growing season. This forage supplemented with a cottonseed meal-salt mixture provided inadequate nutrition for experimental cattle in the winter grazing units. Consequently, a hay supplement had to be added to prevent animal weight losses. Quantity and timing of precipitation, then, can have varying effects on quality and quantity of forage.

Hereford steers on the Delta Experimental Forest, Mississippi, showed no weight gain when forced to subsist almost entirely on browse for ten weeks in the spring and the same length of time in the fall. The steers browsed all tree species to some extent but preferred vines and shrubs, particularly trumpet creeper. Trees having high to medium commercial value were not seriously damaged by spring grazing. In the fall, damage was greater and if continued could easily have reduced the timber stand to an understocked condition.

A five-year study in Louisiana demonstrated that continuous high beef yields are possible when grade cattle graze forest land yearlong, provided they are furnished with protein supplements during fall and winter. Under moderate range use, calf crops averaged slightly better than 80 percent and calves weighed about 435 pounds when marketed at 6 to 7 months of age. Similarly, cow gains and weaned weights of calves in Georgia continue to reflect benefits from supplemental improved forage in the diet of cattle grazing wiregrass-pine range. Average gain in 1960 and 1961 during the 6-month spring-summer grazing season by cows grazing unsupplemented native forage was 35 pounds. Cows on a combination of native range and improved pasture gained 124 pounds. Weaned weight of calves was 367 and 405 pounds, respectively.

In supplemental feeding studies it has been difficult to vary the protein ration between herds while holding other management factors constant; however, use of a common-range technique developed in Alexandria, Louisiana, overcomes much of this difficulty. In this procedure, all cattle graze together as a herd but are trained to go into appropriate pens during feeding periods. In a 2-year trial, the technique worked efficiently when all herds received feed daily. When one feeding treatment was discontinued in the spring, 3 to 5 days of close supervision were required to prevent the cows from transferring to pens of groups still receiving feed. A similar period was required to reorient a group each time a feeding treatment was resumed in the fall.

Results of 15 years' research in Louisiana illustrate possible profits from common cows grazing fenced ranges having ample bluestem forage and adequate watering and handling facilities. For example, from 1956 through 1960, cows fed 375 pounds of protein supplement each during fall and winter and ample minerals all year weaned calves averaging 424 pounds. Sale

prices ranged from 15 cents to 28 cents per pound. Average calf crop was 83 percent, gross annual return per cow was $72.42. Subtracting the $48.85 annual operating cost left a net return of $28.57. This amounts to a 10 percent annual return on a $285 investment per cow.

b. Improved ranges. At Woodland Park, Colorado, highest average weight gain per acre (71.6 pounds) was made by heifers which grazed a mixture of crested wheatgrass (Agropyron cristatum), smooth brome (Bromus inermis), and yellowblossom sweetclover (Melilotus officinalis) during spring-summer-fall months. Highest average daily gain (1.92 pounds per head) was produced by intermediate wheatgrass (Agropyron intermedium); however, this grass did not withstand close grazing. When grazed to a 2-inch stubble, yields declined resulting in fewer grazing days and less beef production than from some of the other species. On the basis of these tests, crested wheatgrass, seeded in mixture with yellowblossom sweetclover, is recommended as best for seeding deteriorated ponderosa pine rangelands in eastern Colorado.

In New Mexico, net returns from lambing on crested wheatgrass pastures were 19 to 27 percent greater than from lambing on native sagebrush range. Optimum use of crested wheatgrass for greatest profit was about 66 percent of the available herbage. Under that use, costs of seeding could be repaid in 4 to 7 years. Lamb crops were 4 to 7 percent larger and death losses 1 to 3 percent smaller on the seeded range as compared to native range.

After 9 years, crested (Agropyron cristatum) and desert (A. desertorum) wheatgrasses continue to be the most productive grasses in both the juniper-pinyon and sagebrush types of the Intermountain region. Heavy mortality was sustained by intermediate (A. intermedium), pubescent (A. trichophorum) and tall wheatgrasses (A. elongatum) on the heavy soil of the sagebrush type, both under grazing and protection. On the lighter rocky soil of the juniper-pinyon type, survival of intermediate and pubescent wheatgrass was excellent, but tall wheatgrass was severely thinned. Russian wildrye (Elymus junceus) survived as well as crested and desert wheatgrasses, but was only about two-thirds as productive. The bearded bluebunch wheatgrass (A. spicatum), failed to persist well on the heavy soil under protection or grazing. On the lighter soil it maintained itself well under protection but virtually died out under grazing. In contrast, a beardless form of bluebunch wheatgrass maintained itself well with either protection or grazing on the lighter soil, but failed on the heavy soil. It appears that the sandier soil, underlain by rocks, can sustain a greater variety of species than the deeper and apparently more productive soils with higher moisture holding characteristics.

Grasses that have persisted as relatively poor stands on the juniper-pinyon site are Great Basin wildrye (Elymus cinereus), bluestem wheatgrass (Agropyron smithii), and Indian ricegrass (Oryzopsis hymenoides). Lack of adaptation of the strains rather than of species probably explains their poor showing. Sparsely scattered plants of Ladak alfalfa have persisted on the juniper-pinyon site. Mountain rye (Secale montanum), smooth brome, thickspike wheatgrass (Agropyron dasystachyum), and streambank wheatgrass (A. riparium) have failed to maintain themselves except as occasional isolated individuals.

Cattle have shown little preference in their selection of the seeded grasses. In contrast, deer and sheep have shown a strong preference for Russian wildrye, particularly in the spring. Preference of intermediate wheatgrass, pubescent wheatgrass, crested wheatgrass, and desert wheatgrass follow in about the order named.

Studies in Louisiana have shown that firebreak strips should be located to take advantage of natural barriers to fire, to avoid sites too wet or dry for good forage plant growth, and to provide a route of travel for fire-fighting crews and equipment. Ordinarily they should be 1/8 to 1 mile apart, dividing the forest into units of 40 to 640 acres. A uniform strip width of one chain is preferred and 1 rod is considered a minimum. To be most effective, firebreaks should be cleared of woody plants, seeded to appropriate mixtures of grasses and legumes, fertilized and limed according to plant and soil requirements, and kept clean by close grazing, mowing, and weed control.

3. Burning For Range Improvement

In Idaho, studies to determine the influence of fire on perennial bunchgrasses have shown that Sandberg bluegrass (Poa secunda) is unaffected by burning at 200° and 400° F. in June, July, or August. Bottlebrush squirreltail (Sitanion hystrix) ranked next in fire resistance, but large plants treated at 400° F. in June or August consistently showed small reductions in basal area. Small plants of Thurbers needlegrass (Stipa thurberiana) were significantly reduced (40 percent) in basal area by burning in June but were not affected in July or August. Basal area of large plants of this species was seriously reduced by fire in all 3 seasons. Needle-and-thread (Stipa comata) appeared to be the most susceptible to fire of the four species tested. Burning killed 95 and 20 percent of the plants in June and July, respectively, and reduced basal area 95 percent in July. Large plants were more susceptible to fire than small ones. For all species, season of burning appeared to be more critical to survival than plant size or intensity of burning.

In Arizona, studies showed that fire killed about two-thirds of the velvet mesquite (Prosopis juliflora var. velutina) seedlings. The remaining one-third of the seedlings were top-killed but sprouted from the base and were usually in sufficient numbers to fully occupy the site in later years if not destroyed.

Five years after a wildfire completely denuded a chaparral site in Arizona, live plant material has increased to 7,100 pounds per acre, green weight. Shrubs account for 91 percent of the composition of which shrub live oak is the major component. Although forbs produced 19 percent of the total plant material in 1958, they contributed only 7 percent in 1960. Perennial grasses, increasing slowly but steadily since the fire, produced 175 pounds per acre in 1960. Weeping lovegrass and crested wheatgrass, seeded after the fire, produced about 27 percent of the grass herbage. Side-oats grama has continued to be the most prominent native grass on the burned area. Apparently, the re-establishment of a predominantly shrub cover can be expected on chaparral sites unless chemicals or other measures are employed to control shrub sprouts.

Forage production on timbered Ozark ranges was found to be inversely related to crown cover and basal area of the timber stand and to competition from weedy herbaceous plants. It has been shown that, when thinning hardwood forests by fire and other treatments to obtain more forage, stands should be thinned to well below 50 percent crown cover. The increase in grass production was small as crown cover was reduced from 80 to 50 percent; however, as crown cover was decreased to below 50 percent, forage production increased rapidly.

In Oregon sprouting of antelope bitterbrush, a valuable forage plant, is closely associated with site conditions. Frequency of sprouting apparently is strongly influenced by texture of the surface soil horizon, stoniness of the soil, and aspect of the site. In a wildfire area which burned in September, stands of bitterbrush supported by loose, coarse textured, non-stony soil on north and east slopes had the highest frequency of sprouting. In one 40-acre area with these site conditions, 80 percent of the burned plants sprouted. In other areas with fine textured, stony soils, as few as 1 percent of the plants sprouted. Such information is particularly important in the selection of areas to be burned for control of big sagebrush.

4. Range Pest Influences and Control

In Colorado where pocket gophers were excluded from Thurber fescue (Festuca thurberi) grassland range, litter and perennial grasses increased substantially in 3 years. Bare soil was exposed on nearly half the ground surface before gophers were excluded. After control, it comprised less than 25 percent of the surface. The amount of litter on the soil surface

increased from 28 percent to 40 percent and grass cover increased from 12 percent to 20 percent. A slight increase was noted in forb cover, from 14 percent to 17 percent. The changes in grasses, litter, and bare ground on both series of plots between 1957 and 1960 were apparently related to the reduced gopher numbers since with fewer gophers, less soil was deposited on the ground surface, less litter was covered by soil deposition, and grasses were disturbed less by burrowing activity.

Native mountain bunchgrass range in good condition on Black Mesa in western Colorado produced 790 pounds of herbage per acre in 1960, of which 445 pounds were grasses and 345 pounds were forbs. Similar adjacent range, sprayed with 2,4-D in 1959 to control forbs, produced 1,791 pounds of herbage per acre in 1960, of which 1,719 pounds were grasses and 72 pounds were forbs. As previously reported, such changes have been accompanied by marked reduction in gopher numbers.

Subsequent food habit studies have explained the correlation between forb production and gopher numbers. The diet of pocket gophers during the summer in Colorado consists of more than 90 percent forbs. Most of this food is in the form of leaves and stems obtained above ground. Among 400 gopher stomachs examined, no grass was found in 38 percent of the stomachs, but forbs were present in all. Limited records to date suggest that the animals rely largely on fleshy roots and bulbs of forbs during the winter.

In big sagebrush areas in northern and western Nevada, protection from small herbivorous mammals for 2 decades has resulted in plant composition changes notably different from changes where livestock only were excluded. The most striking difference was in the greater percentage of perennial forbs that developed under rodent protection.

In Utah relatively severe gopher populations were reduced by half after 1 year of treatment with 1080 grain. Consecutive treatments of 2, 3, and 4 years did little more than hold the population at the level obtained after one year. Apparently poisoning alone can not be expected to entirely eliminate gophers.

Recently published results of the effect of pocket gophers on vegetation following removal of aspen (Populus tremuloides) from a watershed area in Utah showed gophers to be a primary cause of plant cover deterioration under these conditions. Both the aspen-cleared and the uncut areas were protected from livestock grazing. Gophers on the cleared area were nearly twice as abundant and damage to perennial vegetation was much greater than on the uncleared area. It appears that removal of the aspen canopy creates a more favorable habitat for gophers; consequently, such treatment should be accompanied by gopher control measures to prevent excessive damage to the vegetation cover.

In Idaho, three species of insects were found to be particularly damaging to bitterbrush flowers and seeds. During the bud and flower stages, a thrips (Frankliniella occidentalis) caused most identifiable damage by devouring stamens and pistils on approximately 7 percent of 600 flowers examined in early May. Later, when seeds had formed and were still attached to the shrubs, a gall midge and a gelechiid (Filatima sp.) damaged approximately 7 percent and 5 percent, respectively, of 1,100 seeds examined. Additional, less conspicuous damage may occur from punctures made by sucking insects, among which the pentatomid bug (Chlorochroa sayi) was identified as a common seed feeder.

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B. WILDLIFE HABITAT MANAGEMENT

Problem

Wildlife habitat supplies food, cover, and water and is the key to optimum game production. Management of the habitat is complex. Each kind of animal has rather specific habitat requirements, and these must be balanced against requirements for production of water, timber, and forage for livestock. Demands for all uses of forest and related rangelands are increasing, and serious conflicts have developed; consequently, wildlife habitat research is needed to develop the most effective and harmonious management practices for the various vegetation types and associated wildlife.

Specific phases of the problem are: (1) to devise methods for revegetating depleted habitats or improving those naturally unproductive and to develop and evaluate management systems that allow most efficient use of the resource, and (2) to determine the nature and degree of competition between wildlife and livestock on various types of forest and related ranges, effects of timber production and cutting practices on forage for wildlife and livestock, and reciprocal effects of forage production and grazing on timber, particularly reproduction.

Program

This is a continuing, long-term program of both applied and basic research at numerous locations in the various plant-animal communities throughout the United States. It involves interrelations of wildlife and livestock and integration of timber and forage values to allow optimum production and utilization of each. Studies are conducted in cooperation with various State and Federal agencies such as fish and game or forestry departments, Agricultural Experiment Stations, Fish and Wildlife Service, Soil Conservation Service, Agricultural Research Service, Bureau of Land Management, and in some instances with livestock or sportsmen associations, private companies or individuals.

The Federal scientific effort involved in this research totals approximately 20 man-years. Of this amount 12 are devoted to wildlife habitat improvement and management practices and 8 to integration of wildlife, timber, and livestock production.

Progress

1. Habitat Improvement and Management Practices

Antelope bitterbrush (Purshia tridentata) continued to out perform other shrub species being tested for revegetating winter deer range in the Black Hills of South Dakota. Three methods of establishment were used on each of 2 sites: a burned area and a timbered area. Methods of establishment were: (1) potted seedlings transplanted in the spring, (2) seeds planted in the fall, and (3) nursery stock planted in the spring. Survival of potted seedlings was high and all species grew equally well although average growth was no better than with other methods. Three years after direct seeding, antelope bitterbrush plants averaged 11.4 inches high on the burn and 5.5 inches high on the timbered site. Other seeded species, including true mountain-mahogany (Cercocarpus montanus), chokecherry (Prunus virginiana), pincherry (P. pennsylvania), snowbrush ceanothus (Ceanothus velutinus), common juniper (Juniperus communis), silverberry (Elaeagnus argentea), bearberry (Arctostaphylos uva-ursi), inland ceanothus (C. ovatus) and serviceberry (Amelanchier alnifolia) showed generally lower percent germination and survival and poor growth.

Competition is an important factor in bitterbrush establishment. On a good winter range site in California, plant vigor suffered where bitterbrush stocking was more than 2,200 plants per acre. In a test on range seeded to crested wheat it was found that for best results bitterbrush should be planted in the openings and wherever possible at least 2 feet away from each grass clump. This can be accomplished by proper drill spacing and seeding grass and bitterbrush in alternate rows. In an area of current bitterbrush die-off near Mt. Hebron, California, removal of the perennial grass understory nearly doubled bitterbrush leader length and number of leaders per branch.

Similarly, game range restoration studies in Utah show that seedlings of shrubs as a group are more readily killed by competition and drought than are grasses and forbs. Grass seedlings survive drought best and forbs are in an intermediate position. Here big sagebrush (Artemisia tridentata) and rubber rabbitbrush (Chrysothamnus nauseosus) have proven most useful for revegetating big-game winter range. Their rapid growth, high production, ability to reproduce naturally after 3 to 5 years, and fair acceptance as big-game forage are important characteristics of these shrubs. Other shrubs with particularly valuable characteristics are antelope bitterbrush and winterfat (Erotia lanata).

During the past year, a "browse seeder" has been developed, which should prove useful in obtaining more successful establishment of shrubs from direct seeding. Grasses and herbs can also be sown with this machine. It is adapted for use over a wide variety of conditions. The fluted feeds

in the seed boxes and the use of variable scalping wings on the furrow openers are unique features.

Production estimates and relative ratings were made on grasses and legumes planted for elk range improvement at 6,000 feet in 1953 on Sweetgrass Ridge, Washington. Timothy (Phleum pratense), pubescent wheatgrass (Agropyron tricophorum), orchardgrass (Dactylis glomerata), and blue wildrye (Elymus glaucus) maintained excellent stands and high forage production throughout the eight growing seasons. Big bluegrass (Poa ampla), meadow brome (Bromus erectus), slender wheatgrass (Agropyron trachycaulum), dryland timothy, and intermediate wheatgrass stands have fluctuated from fair to excellent. Mountain brome (Bromus carinatus), which maintained an excellent stand through 1955, declined sharply between 1956 and 1960 and is now at the bottom of the list with sheep fescue and hard fescue. Bearded wheatgrass was the only species that failed to produce a satisfactory stand the first growing season. All legumes (Sevelra, Nomad, and Ladak alfalfa; chickpea milkvetch) looked very promising at the end of the first growing season but were rated failures in the third growing season.

In northern Idaho, herbicides show promise for increasing the availability of certain tall-growing browse species on big-game winter range. Stimulation of basal sprouting of Scouler willow (Salix scouleriana) and Saskatoon serviceberry (Amelanchier alnifolia) can be obtained by application of 3 pounds acid per acre of 2,4-D or brush killer (2,4-D + 2,4,5-T). However, redstem ceanothus (Ceanothus sanguineus) a desirable browse, is completely killed by concentrations of these herbicides in excess of 1 pound acid per acre. Late summer spraying may have most promise for rehabilitating such winter ranges.

In Missouri an artificially flooded area (dormant season only) and a normally non-flooded area had about the same total number of acorns (pin oak), but the unflooded area had only about 3/4 as many sound acorns. There was also a lower percentage of insect infested acorns on the flooded area. Dormant season flooding reduced the occurrence of new oak seedlings. On the flooded area in July 1959, there was only one live seedling for every 2,100 sound acorns that dropped in the fall of 1958. On the normal area the ratio was one seedling to 26 acorns. The pin oak trees survived under the conditions of fall and winter flooding that are necessary for the development of duck shooting areas.

At Boise, Idaho on range used in winter at the rate of approximately 12 deer-days per acre, young bitterbrush shrubs established by direct seeding have shown a consistent pattern of regrowth following winter utilization. In October 1957, the mean maximum height of 2-year-old unprotected plants was 4 inches. During the succeeding three winters, deer use averaged 1-1/2, 2, and 3 inches of the current twig growth

the total of which averaged 3-1/2, 4-1/2, and 5-1/4 inches. As a result, unprotected plants had a mean maximum height of 10-1/2 inches after 5 growing seasons. Bitterbrush in an exclosure protected from browsing had a mean maximum height of 3-1/2 inches in October 1957. Growth averaged 4-1/4, 4-1/2, and 5-3/4 inches the following 3 summers, and the mean maximum height of plants after 5 growing seasons was 18-1/4 inches. Average maximum crown diameter was nearly equal to the average maximum height of the browsed and unbrowsed plants, i.e., 10 and 18 inches, respectively. Holding utilization of young bitterbrush to a level that will permit establishment is a real problem in practical game range revegetation operations.

Studies of mule deer herd productivity in the Intermountain area show that summer range condition is a very important factor. A herd on a very poor summer range in central Utah produced only two-thirds as many fetuses or newly born young as a herd on a very good summer range in southern Idaho. The importance of good winter range to deer herd production has been previously demonstrated, but summer range has not been generally regarded as a limiting factor.

Research in Oregon has illustrated the need for deer herd habitat management on the basis of natural plant communities or habitat types. Grouping deer rumen analysis samples for volume and frequency of ingested plant material with classified habitat types has shown that some browse species such as ceanothus (Ceanothus velutinus), pine manzanita (Arctostaphylos parryana pinetorum), and big sagebrush supply important parts of the deer diet in particular habitats. In some areas these species, often considered unimportant game forage plants, contribute at least 50 percent of the diet. Therefore, management of a herd unit must consider each part of the habitat complex instead of handling the total unit as a single entity.

In Utah, forage preferences of antelope in early summer are chiefly for forbs. These plants made up 49 percent of the estimated diet during June and early July while grasses contributed 34 percent and shrubs only 17 percent. The more important plants were evening primrose (Oenothera sp.), Indian ricegrass (Oryzopsis hymenoides), black sagebrush (Artemisia nova), and mallow (Sphaeralcea sp.). These species comprised 80 percent of the diet under light grazing on good condition semidesert shrub range. Normal diets of antelope and deer, then, are considerably different, and competition of these two game animals should not be serious where their ranges overlap.

2. Integration of Wildlife, Timber, and Livestock Production

Foliage cover of shrubs, grasses, and forbs increased on two deer winter range study areas in the Fisher River drainage, Montana, during the years 1949-1959 as a result of opening the timber stand by logging. Significant increases in understory vegetation occurred in areas open to both light and heavy deer use as well as in areas closed to deer. Shrub cover increased more than grasses or forbs in all areas. It is expected that this improvement in deer forage will result in less damage to reproduction of ponderosa pine.

Somewhat similar results have been obtained in Oregon and Washington after thinning dense stands of ponderosa pine saplings to different spacing levels. In Oregon, combined grass-forb-browse production is more than twice as great in any of five variously thinned stands as in unthinned stands. Stands thinned to 6.6- and 18.7-foot spacings showed the greatest production (230 pounds per acre as compared to 88 pounds per acre in unthinned stands). In Washington, greatest herbage production occurred in stands thinned to a 13-foot spacing (283 pounds per acre as compared to 172 pounds per acre in unthinned stands). Most increases in production resulted from increased development of residual plants rather than from establishment of new individuals.

Likewise, two years after removing hardwoods from a loblolly-shortleaf pine-hardwood forest in Louisiana, herbage yields of grass and browse species increased more than four times. Grass yields showed the greatest response, increasing from 70 pounds per acre to 440 pounds per acre. Browse yields increased from 67 to 163 pounds per acre.

Forage yield can be greatly increased on oak-hickory-little bluestem ranges in Missouri by aerial spraying with 2,4,5-T, summer burning as a seedbed preparation, seeding adapted forage species, and fertilizing. Herbage yields the first year after spraying increased from 50 to 400 pounds per acre on unseeded areas, to 600 pounds per acre on areas seeded to a mixture of native grasses, and to nearly 1,000 pounds per acre on areas seeded to a tame grass-legume mixture. Adding commercial fertilizer (320 pounds of 8-24-8 per acre) further increased yields on both seeded and unseeded areas by 50 to 150 percent. Summer burning as a seedbed preparation and to reduce understory hardwood competition nearly doubled herbage yields under all treatment combinations.

Cultivation of pine trees planted in an old carpetgrass (Axonopus affinis) field in south Georgia increased growth of trees significantly. By the end of the third growing season, trees that had been cultivated 2 or 3 times each year with a tandem disk-harrow measured 32 inches in height and those not cultivated measured 24 inches. Cultivation, then, shortens the period during which the trees may be injured by grazing. Preliminary

results indicate that as much as 75 percent of the foliage can be removed without affecting initial survival of slash pine seedlings; however, as little as 25 percent foliage removal has an adverse effect on growth rate.

Studies on the evaluation of deer and elk habitat in relation to livestock summer range in Utah indicate that deer and elk prefer native range types to seeded grass stands in late spring and in the fall. Pellet group studies showed that in aspen and browse range types, animal-days use per acre was 13.5 and 10.0, respectively. This compares to only 0.14 animal days use per acre for a good mixed stand of crested wheatgrass and smooth brome. Apparently, competition of elk and deer with livestock for use of seeded range is not serious if sufficient native range is available for the game.

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WORK AND LINE PROJECTS, Range and Wildlife Habitat Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-r1	TAXONOMY, ECOLOGY, PHYSIOLOGY														
-1	Plant identification		x		x	x		x		x	x			x	III, A-1-b
-2	Ecology and physiology		x	x	x	x	x	x	x	x				x	III, A-1-a
-3	Forage values					x			x	x	x			x	III, A-1-c
FS 1-r2	MEASUREMENT, SAMPLING, DESIGN														
-1	Measurement techniques		x	x	x	x	x		x		x				III, A-1-d
-2	Sampling and experimental designs		x							x	x				III, A-1-d
FS 1-r3	MANAGEMENT, LIVESTOCK RANGE														
-1	Grazing management-native range		x	x	x	x				x	x				III, A-2-a
-2	Grazing management-improved range			x	x	x				x					III, A-2-b
-3	Influencing distribution and supplementation		x		x	x				x	x				III, A-2-a
-4	Range condition and trend		x			x				x	x				III, A-1-a
-5	Use of fire		x			x				x	x				III, A-3
FS 1-r4	WILDLIFE HABITAT MANAGEMENT														
-1	Big-game grazing management		x	x	x	x					x				III, B-1
-2	Habitat condition and trend		x							x					
-3	Habitat improvement		x	x	x	x	x	x	x	x	x				III, B-1
FS 1-r5	RANGE USE RELATIONS														
-1	Range-timber relations		x	x	x	x	x	x	x	x	x				III, B-2
-2	Game-livestock relations		x		x						x				III, B-2
-3	Range-watershed relations		x			x		x							

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
PSW - Pacific Southwest
INT - Intermountain
RM - Rocky Mountain
LS - Lake States
CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
WO - Washington - Beltsville

WORK AND LINE PROJECTS, Range and Wildlife Habitat Research DIVISION
FOREST SERVICE, U. S. D. A.
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Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year[1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 1-r6	RANGE PEST RELATIONS														
-1	Rodent-range relations				x	x									III, A-4
-2	Insect-range relations		x		x										III, A-4

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IV. FOREST FIRE RESEARCH

Problem

Forest fires are a constant threat to profitable long-term investments in intensive forestry. In 1960, the estimated total direct cost of wildland fire control in the United States was about $100 million. In 1962, it is estimated to be about $140 million, up about 40 percent. Nationwide, forest fires number over 100,000 a year and burn over about 6 million acres of land. These figures vary somewhat from year to year with length and severity of the fire season, but recent years have shown no meaningful downward trend.

For a number of years 90 percent of the costs and damage from fire have been caused by fewer than 5 percent of the total fires that start. Yet there is still lack of the kind of knowledge that will enable fire control specialists to identify the potential runaway fire early in its life. Neither have fire fighting methods been developed capable of controlling the more aggressive fires, even when attacked promptly and while still small. The most urgent problem is to find ways to stabilize the rapidly increasing fire costs and to find new ways to reduce fire numbers and area burned. Only slightly less important is the need to develop safe and effective techniques for using fire purposefully on wildlands as a direct protection measure and for other land management purposes.

Program

The Forest Service has a continuing long-term program involving numerous disciplines in the physical, biological and social sciences engaged in both basic studies and application of known principles to the solution of wildland fire problems. The research is conducted at the Macon, Georgia; Missoula, Montana; and Riverside, California Forest Fire Laboratories as well as at projects in Fairbanks, Alaska; Portland, Oregon; Berkeley, California; Fort Collins, Colorado; Salem, Missouri; St. Paul, Minnesota; Upper Darby, Pennsylvania; Asheville, North Carolina; and Alexandria, Louisiana.

Weather and fire behavior research at the three fire laboratories and at Portland, Salem, and Alexandria is cooperative with the Department of Defense, Weather Bureau, National Science Foundation, National Bureau of Standards, State conservation agencies, universities and other research institutes. Fire prevention studies relating to man-caused fires at Riverside and Alexandria are cooperative with the University of Southern California and the Universities of Louisiana and Mississippi, respectively. Lightning prevention research at Missoula is cooperative with National Science Foundation, Weather Bureau, Montana State University and University of Washington. Fire control systems and methods research

at all locations is cooperative with State and local conservation agencies, universities, field offices of other Federal agencies, private landowners, and private industry. Use of fire studies are cooperative with State and local conservation agencies, Weather Bureau, universities, and public and private land managers.

The current Federal scientific effort devoted to this research is 56 professional man-years. This includes 23 to weather and fire behavior; 6 to fire prevention; 21 to fire control systems and methods; and 6 to fire use.

One fire behavior study is conducted by Instituto Nacional de Tecnica Aeronautica Esteban Terradas, Madrid, Spain under PL-480 contract.

The Forest Service is the only Federal agency which conducts forest fire research. Other Federal agencies conduct or sponsor research on fire problems relating to missions other than forestry, and all of them, in common with the Forest Service, have interest in basic laws and principles of combustion and extinguishment. Work is coordinated closely through several mechanisms. Some States and universities conduct short-term forest fire studies, though mostly through cooperative agreements with the Forest Service.

No major lines of work were terminated during the year.

Progress

1. Weather and Fire Behavior

a. Fire physics. A better understanding of the fundamental processes of ignition, combustion, and fire behavior is essential for more effective forest fire control. At Berkeley, California much evidence is accumulating to indicate that many of the differences in combustion properties which were previously attributed to changes in the major constituents of cellulosic fuels are at least partially due to changes in the small amounts of inorganic components. Reducing the ash content of purified cellulose from 0.1 percent to 0.01 percent can have a marked effect on its sensitivity to heat.

A series of test crib fires at the Macon Forest Fire Laboratory show that rate of spread and rate of burning, or fire intensity per unit area, are inversely proportional to the square root of the fuel moisture content, to the fuel specific gravity, and to the fuel size raised to the 1.5 power. The range of fuel moisture studied was from 2.5 to 16.7 percent; wood specific gravity ranged from 0.30 to 0.82.

Other studies at Macon indicate that the timelag interval in fuel drying scales as the square of the appropriate fuel dimension. The timelag study has shown that there is a close relationship between the drying process and the burning process; consequently, the timelag interval is a useful parameter for estimating both how fast a fuel will dry and how fast it will burn.

Fires burned in the combustion room in the Missoula Forest Fire Laboratory showed that rate of spread may be quite independent of other combustion characteristics of fires in different kinds of fuel. Under the same rates of fire spread in beds of different fuels, radiant flux, convection column temperatures, and fuel consumption varied considerably.

b. Fire characteristics. Improvement in fire control technology needs better information on time-temperature relations in all kinds of fire situations. Experimental fires in a 14-ton-per-acre longleaf pine litter produced maximum temperatures approximating 1600° F. On the windward side of a tree, maximum temperature decreased from the groundline upward. On the leeward side, location of the maximum temperature mark was somewhat elevated. Fire temperatures on the lee side of a tree were higher, persisted longer, and extended higher on the bole than on the windward side. Head fires and backfires burning under the same weather conditions produced temperatures at the groundline of equal magnitude and duration.

Although the same general time - temperature relationships obtained for fires in heavy coastal plain fuels were evident in Piedmont fires of the South, peak temperatures were generally lower.

c. Fuel measurements. Learning to identify fuel variations that affect fire behavior is an important current need.

Periodic observations have shown that the moisture condition of chamise foliage in California is a good indication of the chances of a bad fire. The moisture content of this living fuel is closely related with soil moisture; when it is at a low level, fires burn more intensely and are more difficult to control.

In south Georgia, on the other hand, the average moisture content of live palmetto and gallberry plants was found to remain fairly constant from year to year regardless of the precipitation, soil moisture, or other weather influences. Fluctuations in the quantity, condition, and arrangement of dead fuels, therefore, are apparently responsible for differences experienced in the ignition and behavior of forest fires in the palmetto-gallberry fuel type.

d. Weather and topography. Topography complicates local weather and makes it behave in peculiar ways. In east-facing canyons in the coastal mountains of California, the daytime thermal up-canyon winds are frequently replaced, usually in early afternoon, by a moderately strong down-canyon wind. The same type of wind has also been noted in the western foothills of the Sierra Nevada. This shift in the wind to down canyon is important in wildland fire control and has been a factor in some fire-fighting fatalities. A survey in the summer of 1961 shows evidence of a wind surge moving from the coast inland during the day. Indications are that the penetration of the marine air inland is controlled by the depth of the marine layer and strength of the advection.

Invasion and recession of marine air in the mountains of southern California has been shown to be a prominent characteristic of the summer climate of this region. At night, the marine air is frequently in a relatively shallow layer in the coastal lowlands, leaving much of the mountain areas exposed to comparatively dry air. During the day, thermal winds aided by the sea breeze cause turbulent mixing that brings moist air to higher levels. This frequently results in an increase in daytime relative humidity at the higher levels despite an increase in temperature. At night when solar heating ceases and downslope drainage winds set in, the marine air recedes to lower levels again and dry air subsiding from aloft takes its place. Lowland areas remaining in the marine layer have the normal pattern of increasing humidity at night and decreasing humidity during the day.

The final analysis of ten years' records confirms that westerly winter winds in the Southeast are more persistent than winds from other directions. The application, of course, is that these winds should be given more consideration in selecting conditions for prescribed burning. Most cases of low humidity in this region were shown to result from advection of cold dry air from north and west quadrants.

In the Pacific Northwest, fire-weather research efforts have found ways of defining the vertical extent of layers in which mixing is present (unstable layers) and of layers in which there is no mixing (stable layers). Within the mixed layers, temperatures and humidities can now be adjusted between elevations. Predictions of tomorrow's fuel moisture can be made from the forecast relative humidity and today's observed fuel moisture.

e. Correlation of fire and environment. Cause and effect relationships in fire behavior are extremely complex. At Macon, Georgia, thermally driven fire whirlwinds ranging in size from a few inches to eleven feet in height were produced in the laboratory in specially constructed convection chambers. Experiments with these enclosed whirlwinds are expected to reveal the significant factors involved in the formation and development of the larger-scale fire whirls often experienced in fire fighting.

f. Case history studies of fire behavior. Intensive study of individual large fires often reveals new information. The rapid spread of fire by spotting has been shown to accompany turbulent eddying of down-canyon drainage winds in several of California's bad fires. Ordinarily, long-distance spotting has been linked to unstable lapse rates. The theory is that an unstable atmosphere permits higher combustion rates and that, with increased fire intensity, heavier material is lifted into the convection column and carried farther before dropping out. In heavy fuels such as timber, experience bears out this theory. However, in grass and light brush where all the embers are small-sized, the reverse is true. With unstable lapse rates, embers tend to burn up completely before reaching the ground. The ideal stability pattern for long-distance spotting in light fuels is one in which convection is limited to a few hundred feet above the ground and embers have a relatively flat trajectory.

2. Fire Prevention

a. Preventing man-caused fires. Sociological research must reveal some of the clues needed for more effective fire prevention effort. In California, survey figures show that fire agencies and other conservation groups are doing an effective job of selling fire prevention to hunters. The reasons given by hunters for being careful with fire, however, depended on the section of the State where each resided and the local problems involved. This may indicate the need for a broader fire prevention message.

b. Project skyfire. Through a series of randomized experiments, the Missoula Forest Fire Laboratory continued study of the physical aspects and results of seeding lightning storms. A preliminary analysis of 2 years' data indicates an apparent reduction of 38 percent in cloud-to-ground lightning in storms treated with silver iodide.

c. Hazard reduction. The judicious use of fire and other land treatments can reduce dangerous fuel concentrations to manageable levels. Hazard reduction burns on the Osceola National Forest in Florida and Francis Marion National Forest in South Carolina have shown that short burning intervals of 2 years or less require the use of striphead firing techniques for repeat applications. This burning procedure is resulting in greater hazard reduction at less cost.

Our Fuel-Break project in southern California has been concerned primarily with treating critical fuel areas, controlling sprouting brush species, and developing "fire-resistant" cover crops. A combined treatment of mechanical clearing followed by hormone sprays continues to show the greatest promise of success. Wheatgrasses have been outstanding for sowing at the higher elevations where growing conditions are usually unfavorable for most grass species. Extensive aerial sowing of many different grasses on the burned-over portions of the San Dimas Experimental Forest has shown the desirability of early fall sowings and the advantages of drill sowing and north exposures.

3. Fire Control Systems and Methods

a. Detection. Prompt and reliable detection of wildfires is a goal of any fire control organization. Studies in Montana by the Missoula Forest Fire Laboratory show that the use of airborne infrared scanning devices for identifying small heat sources is physically feasible. Such devices theoretically can also determine the location of fire lines on large fires and provide records of the rate of fire spread.

The 3 cm, SO-12 M/N radar set identified and tracked developing and mature lightning storm cells at reliable ranges to 80 miles. The radio-direction finder unit used with the radar did not, however, give reliable or satisfactory readability for determining electrical activity within the storm cells.

b. Fire danger rating. The Wildland Fire Danger Rating Handbook for California was completely revised during the year by the Pacific Southwest Forest and Range Experiment Station and its cooperators. Burning indexes can be computed for grass, brush, or timber fuels and combined with a fire ignition index to give a fire load index.

A 2-index system of rating forest fire danger for the ponderosa pine forests of the southwest has proved reliable. Based on drought index and rate-of-spread index, this system has consistently pointed out the bad fire days for the past five years.

Mean wind speeds for short intervals are often poor indicators of potential fire behavior. To provide a better gage, the Central States Forest Experiment Station has developed a gust meter that permits the estimation of probable 1-minute extremes and maximum gusts for different mean wind speeds measured over a 10-minute period.

Good progress is being made in the development of a national fire danger rating system. The system includes a spread index and a buildup index that are now being checked in the field. Data from selected study areas in the United States are being used to provide the basis for an analysis to determine the performance of the national system for the country as a whole and for comparisons with existing systems.

c. Fire suppression. Increasing use of aerial attack emphasizes the need for aggressive research to assure high efficiency. Calibration trials with Florida's C-45 aerial tanker proved the desirability of using thickened retardant mixtures when making certain aerial fire attacks. Dropping elevations could be increased without an appreciable decrease in the size or concentration of the resulting ground pattern.

In Georgia, slurry drops through a bare hardwood canopy suffered less payload loss due to crown interception than in pine canopies. In the growing season, on the other hand, hardwood drops are not practical unless loads greater than 500 gallons can be released at one time.

Refinements in the application and characteristics of present fire retardant materials such as borate, bentonite, and ammonium phosphate have continued. In addition, many new chemicals and formulations have been evaluated at the fire laboratories. Trials at Missoula rated Fire-Trol, Algin DAP, and Pectin DAP at the top of their list. In California, viscous water and algin gel have effectively demonstrated a superiority in attacking hot fires in a wide variety of fuels. The work at Macon, Georgia is revealing that certain local clays have use as thickening and adhesive agents.

After two years in the field, Slash pine seedlings planted in monoammonium phosphate drop zones in south Georgia had over 50 percent greater height growth than either the borate or check plot trees.

Fire research personnel for the fourth consecutive year organized and conducted a national fire behavior training school. The purpose is to raise the level of competence among fire suppression strategists in interpreting and predicting short-term changes in the behavior of large fires that affect the suppression job.

d. Fire equipment. Systematic testing is a normal part of equipment development. In cooperation with the Michigan Forest Fire Experiment Station, the Model IV Sand Caster was evaluated for its fire-fighting potential in Michigan, Georgia, and Florida. The principle of machine casting sand to control wildfires was judged sound. When cast in quantities, sand was capable of extinguishing flames; when used to pretreat fuels, it afforded resistance to ignition and reduced both the rate of spread and intensity of forest fires.

The Superior National Forest and the Lake States Forest Experiment Station cooperated in testing the water-drop pattern of a pontoon-equipped DeHaviland Beaver. Equipped with a snorkel loading tube that filled a 125-gallon tank in about 14 seconds while taxiing across a lake, the plane produced satisfactory drop patterns although application rates were lower than is desirable. A larger release hatch is expected to improve this application rate.

4. Use of Fire

a. Direct fire effects. Knowledge of the lethal temperatures and the protective adaptations of plants is necessary for the practical use of fire for protection or other management purposes. Inasmuch as bark is one of the more important protective adaptations, its insulating properties are being studied at the Macon Fire Laboratory. The thermal conductivity

of bark displayed a strong positive correlation with density and moisture content. Directional conductivity tests indicated that the greatest conductivity in bark was in a longitudinal direction and least along the radial component, although the ratios of longitudinal to radial or tangential conductivity were not as great as in wood.

Field measurements in Louisiana show that rather minor irregularities in the bark surface affect local temperature regimes. Maximum temperatures on a ridge or plate can be several hundred degrees higher than in an adjacent shallow fissure and tend to persist for a longer period of time. This undoubtedly partially explains the relative fire resistance of heavily-furrowed tree stems.

A slow-moving controlled backfire in shortleaf pine in Missouri, top-killed 83 percent of 1- to 7-foot tall, 3-year-old trees. Taller trees were less susceptible to injury than shorter trees. Basal sprouts occurred on 77 percent of all the trees, whether they suffered top-kill or not. The trees that did not sprout were the smaller ones that had their crowns consumed by the fire.

In well-stocked loblolly pine stands in Georgia's Piedmont area, single prescribed fires on slopes of less than 15 percent resulted in no appreciable soil movement during the first year following burning. The only pine mortality incurred was in the smaller size classes, and then only to suppressed trees in the understory.

Prescribed headfires in Texas killed back more hardwood stems than pine stems. Fires in the growing season reduced hardwood understory more and killed more pine than fire during the dormant season. Most of the damaged pines were killed, while about 90 percent of the injured hardwoods resprouted from the rootstock. Sweetgum proved more susceptible to fire injury than oak -- almost twice as many sweetgums as oak were killed back and over three times as many were completely killed. One- and 2-inch stems of all species were more effectively controlled than larger stems.

b. Techniques for prescribed burning. The benefits from prescribed fire depend in part on how well the burning technique is matched to the environment. Arizona chaparral was made to burn satisfactorily in reasonably safe weather after crushing with a tractor, provided the stand was dense enough to form a continuous bed of fuel after crushing. Southwest chaparral stands are generally not dense enough, however, to make this feasible. Chemical desiccation was found best of several chemical treatments for increasing chaparral flammability.

In the Northwest an electric wood-moisture meter was used to measure the dryness of slash when burned. When the indicated moisture 1/8 inch below the surface of logs was less than 19 percent, slash fires spread satisfactorily. In using this instrument it was found necessary to use considerable care in selecting sampling spots.

Summer test burns on the Hitchiti Experimental Forest in Georgia inflicted more damage to undesirable hardwoods and brush than dormant season burns. Upslope strip fires continued to show the greatest promise in the control of unwanted understory species and appear to be the only practical firing technique for repeat burning on Piedmont slopes. In burning on slopes, use is made of the effect of slope on fire spread to offset undesirable effects of local wind.

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WORK AND LINE PROJECT, Forest Fire Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 2-f1	FIRE BEHAVIOR														
-1	Fire physics			x	x					x					IV, 1-a
-2	Fire characteristics									x	x				IV, 1-b
-3	Fuel measurement		x		x	x	x	x		x	x				IV, 1-c
-4	Weather and topography		x	x				x		x					IV, 1-d
-5	Correlation of fire and environment		x	x	x			x	x	x					IV, 1-e
-6	Case history studies of fire behavior			x	x					x					IV, 1-f
FS 2-f2	FIRE CONTROL														
-1	Fire control standards and objectives														
-2	Fire control planning			x	x					x					
-3	Detection systems				x										IV, 3-a
-4	Initial attack systems		x						x						
-5	Fire danger rating	x	x	x	x	x		x		x	x			x	IV, 3-b
-6	Fire training			x	x					x				x	IV, 3-c
-7	Fire prevention			x							x				IV, 2-a
-8	Hazard reduction			x	x	x				x					IV, 2-c
-9	Weather modification				x										IV, 2-b
-10	Fire extinguishment			x											IV, 3-c
-11	Fire suppression			x	x		x			x	x				IV, 3-c
-12	Fire equipment						x	x							IV, 3-d
-13	Case history studies							x	x		x				IV, 3-c

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
PSW - Pacific Southwest
INT - Intermountain
RM - Rocky Mountain
LS - Lake States
CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
WO - Washington - Beltsville

WORK AND LINE PROJECTS, Forest Fire Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 2-f3	FIRE EFFECTS														
-1	Direct fire effects				x			x		x	x				IV, 4-a
-2	Indirect fire effects										x				IV, 4-a
-3	Fire benefits and damages								x	x					
-4	Case history studies			x					x						
FS 2-f4	FIRE USE														
-1	Techniques of fire use		x	x		x				x					IV, 4-b
-2	Results of fire use			x						x					IV, 4-b

[1] Research Locations

NOR - Northern
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V. FOREST INSECT RESEARCH

Problem

Insects are among the most destructive of all the agents affecting the forests of this country. Each year they not only kill, weaken, degrade, or reduce the growth of vast quantities of valuable commercial sawtimber but, also, of large volumes of smaller-size timber. During periods of outbreaks, which occur frequently in many parts of the country, losses are much more severe, often bordering on the catastrophic. Losses are not confined to timber alone: watersheds and wildlife habitats are impaired and fire dangers are increased. Insects also damage or destroy the seeds and cones of trees, thereby jeopardizing the success of seed orchards and natural regeneration programs; they infest browse plants on forest-related ranges, thereby lowering their carrying capacities for livestock and big game; and they damage or destroy huge quantities of forest products, such as logs, lumber, and pulpwood each year. More information is needed on the causes of forest insect outbreaks; on the development of long-lasting silvicultural and biological control methods; and on the development or improvement of chemical controls that can be applied economically and without undue hazard to fish and wildlife.

Program

The Department has a continuing long-term program involving forest entomologists, insect ecologists, insect physiologists, insect pathologists, microbiologists, and photo interpreters engaged in both basic and applied studies directed toward the development of safer and more economical and effective methods of direct and preventive control of forest insects. Research is underway at the 10 Forest and Range Experiment Stations, Forest Products Laboratory, and Beltsville, Maryland Forest Insect Laboratory. The program is cooperative with various universities, State Experiment Stations, industries, other Federal and State Agencies, and Canada Department of Agriculture. The University of Connecticut assists in studies of bacteria in insects; Brookhaven National Laboratory, in studies of male sterilization of the gypsy moth by gamma irradiation; New York State Museum and Science Service, in ecological studies of the gypsy moth; University of California, in studies of insects affecting seeds and cones of Douglas-fir; National Park Service, of lodgepole needleminers in Yosemite National Park; Ohio Agricultural Experiment Station, studies of the locust borer. Agricultural Research Service cooperates in introduction of insect parasites and predators from abroad. PL-480 projects are underway in Finland, Poland, Spain, Pakistan, and India on forest insects, with emphasis on the introduction of parasites and predators of important species.

The Federal scientific effort devoted to research on forest insects totals 81 man-years per year.

Several chemical companies supply materials for testing as systemics, and for control of wood products insects. Weyerhaueser Timber Co. conducts research on insects affecting Douglas-fir. The University of Wisconsin studies plantation insects; University of Connecticut, the gypsy moth; and University of Michigan, borers in aspen.

Progress

1. Biological Control

It is the general consensus that populations of most native forest insects are held to sub-economic levels by their natural enemies, such as parasites, predators and disease pathogens. Even where outbreaks occur, populations sooner or later are brought back to normal levels by these agents, even though no direct control action is taken. Introduced insect pests may become extremely destructive because of the absence of natural enemies. Here, it is often possible to remedy situations by introducing these agents into infested stands from the native homes abroad of these pests. It has been found possible to secure control of some insects through interference with their reproductive capacities. Some biological control factors such as viruses and bacteria can be formulated into sprays and applied to control active infestations of certain insects. Generally speaking, biological control is cheaper, safer, and longer-lasting than conventional methods of insect control.

a. Parasites and predators. Preliminary studies show that Coeloides brunneri Vier, the most abundant parasite of the Douglas-fir beetle in the Northwest, enters diapause either during the fifth larval instar, or not at all. They also show that the portion of the population entering diapause is influenced by the length of day; and that the adult female parasite is receptive to the photoperiod stimulus, which determines whether or not her progeny enters diapause.

Recent studies indicate that several species of parasites of the gypsy moth that have previously been considered of minor importance in control may, in fact, be quite effective. In the past, the parasites in question - Itoplectis conquisitor, Theronia atalantae, T. hilaris and Coccygominus pedalis - have never been reared in large numbers from gypsy moth larvae. This suggested their ineffectiveness in control. Recently, it has been found that these species kill far greater numbers of their host by stinging than by parasitization. For example, I. conquisitor killed more than 200 times as many by stinging than by parasitization. This mortality caused by stinging had not previously been known to be so effective. The real significance of this finding is yet to be determined. It could be most important in evaluating the control effectiveness of different parasite species.

During the past 5 years, a total of 18 species of important parasites of fifth and sixth instar larvae of the spruce budworm were collected in the Lake States. In addition, 8 species were collected from budworm pupae. There was very little difference in percentage parasitization between trees in different crown classes. In contrast, differences were fairly great among different crown levels. This indicates that while no special consideration needs to be given to crown classes in sampling budworm populations for parasitization, all crown levels in a tree should be sampled.

An incipient outbreak of the black-headed budworm on western and mountain hemlock on Mt. Hood National Forest apparently was suppressed by parasites, at least 10 species of which were found attacking fourth-instar budworm larvae, with a total parasitization of 70 percent. This high degree of control was obtained before budworm feeding damage could be detected from the air.

During the past 12 years, all known gypsy moth infestations on Cape Cod, Massachusetts, have been sprayed intensively with DDT. Recently, a survey was made to determine the effects of this spraying on parasites of the gypsy moth which were introduced from abroad and established in the area several years ago. A total of 2,000 gypsy moth eggs, 600 larvae, and 600 pupae were collected in 1960 from three different infested areas, and placed in rearing for the issuance of parasites. Recoveries showed that 7 species, or all but two of the important species of gypsy moth parasites introduced from abroad and successfully established in this country, were still present on Cape Cod despite their exposure to the intensive spray program conducted during the previous 12 years.

In the Lake States populations of the spruce budworm increased in stands where aggregate parasitization was less than 60 percent, and decreased where it was greater. In Montana, two species of hymenopterous parasites, Glypta fumiferanae and Apanteles fumiferanae, were responsible for a considerable portion of the parasitization of the spruce budworm. However, their effectiveness was materially reduced by the prevalence of hyper-parasites.

In Oregon, a form of the spruce budworm has been found that differs both in larval color and feeding habits from the regular form. In recent studies populations of this form of the budworm were found to be seriously affected both by a virus-like organism and the parasite Lypha setafacies. This was not only the first record of this disease affecting the budworm in the region, but it was also the first instance on record of significant parasitization by L. setafacies. The possible significance of these findings is yet to be determined.

During the past few years several species of insect predators of the balsam woolly aphid have been introduced from abroad and liberated in fir stands infested by the balsam woolly aphid in the Pacific Northwest and southern Appalachians. So far, 5 species are known to be established in the Northwest and 3 in the Southeast. One species, Laricobius erichsonii offers promise in reducing aphid populations. In the Northwest it is spreading slowly, having been recovered at least 1,400 feet from the point of release. During the past year, several hundred predators, representative of at least 6 different species were introduced into the Southeast from Germany, India and Pakistan. Further studies are needed to determine the value of this program of introduction of foreign enemies of the aphid.

Valuable information was obtained on the habits of woodpeckers which provide such excellent natural control of small outbreaks of the Engelmann spruce beetle in Colorado. Three species of woodpeckers - the northern three-toed, the hairy, and the downy - were found in infestations of the beetle in about equal numbers in a high altitude spruce-fir forest. All three overwintered in this forest. During the spring the downy and hairy species moved down to lower elevations but the three-toed remained at the higher one. During daylight hours of the winter all species aggregated at beetle-infested trees; at night they dispersed for distances up to one-half mile. No large aggregations of birds were observed during the breeding season.

About 5,000 parasites of the European pine shoot moth were introduced from Germany and liberated in 8 different locations in Lower Michigan in 1961. The following species were represented in these introductions: Orgilus obscurator, Bracon brevicomis, Tetrastichus turionum, Itoplectis examinator, Scymnus suturalis, Scambus sp., Pristomerus sp., and Temelucha sp. An unidentified parasite was reared from 90 percent of Great Basin tent caterpillar egg masses collected in the Southwest and held in rearing; however, only 5 percent parasitization of the eggs in the masses occurred. Tent caterpillar larvae killed by a polyhedrosis virus were present in over 90 percent of the larval colonies examined; also at least 25 percent of the pupae were parasitized. Despite the mortality caused by these agents, more than 10 new egg masses were deposited on each tree in the study area -- or enough to continue the outbreak.

In Mississippi the parasite, Trichogramma sp., destroyed 24 percent of the eggs of Laspeyresia ingens, a pest of the cones of longleaf pine. The parasites, Hyssopus johonsoni, Phanerotoma fasciata, Agathis sp., and Calliephialtes comstockii and the predator, Cymatodere undulata also destroyed 17 percent of the larvae. An additional loss of 33 percent of the population resulted from cannibalism and starvation.

The beetle, Enoclerus numerensis, appears to be an effective predator of Barbara colfaxiana, a pest of the seed and cones of Douglas-fir in California. There was no emergence of the latter from cones harboring the beetle.

b. Disease pathogens. One of the most important natural control factors affecting the gypsy moth in the Northeast is a polyhedral virus, Borrelina reprimens Holmes. Its mode of transmission has long been a matter of conjecture. Recently, it was found to be carried both on and in gypsy moth eggs, with surface contamination being the more effective mode of transmission.

Three dosages of a spore-crystal concentrate of Bacillus thuringiensis were applied by airplane to a series of woodlots 25-200 acres in size heavily infested by the gypsy moth in New York. Each of three dosages 1/2 lb., 1 lb., and 2 lbs. in 2 gallons of water per acre were applied to 2 plots. An additional plot received 1/4 lb. plus 4.8×10^{10} polyhedra of the gypsy moth virus in 2 gallons per acre. Tung oil was used as a sticker. Defoliation by the gypsy moth was materially reduced in the treated plots. Best results with B. thuringiensis alone were obtained with the heaviest dosage - 2 lbs., in 2 gallons of water (plus tung oil) per acre. The bacillus-virus spray gave approximately as good control as did this dosage.

In laboratory and small field studies, Bacillus thuringiensis was toxic to the spruce budworm when applied at dosages greater than 2 lbs. per acre. Additional studies are needed to determine the effectiveness of the material when applied on a large scale in a control project. B. thuringiensis was also found to give a high degree of control of the southern powder post beetle within 48 hours, when applied as a dust in the laboratory.

Adult females of Ips confusus, an important bark beetle pest of pine in the Southwest, are less vigorous when infested with the nematode Aphelenchulus elongatus than are non-infested ones. Infested females constructed shorter egg galleries than non-infested ones and produced only about one-third as much brood. When the female parent alone contained egg-laying nemas the progeny was 47 percent infested; only about 6 percent of these were infested when the male parent alone was infested.

Adults of Ips lecontei a destructive bark beetle in the Southwest, contain adults and eggs of the parasitic nematode, Aphelenchulus sp.; pupae contain mature or nearly mature nematodes; and larvae contain nematode larvae. Studies indicate that the life cycles of the insect and its nematode parasite are almost exactly synchronized; also that the nematode completes its life cycle in less than 25 days.

In the Central States, populations of the scale, Toumeyella liriodendri (Gmelo), an important pest of yellow poplar, were completely controlled on isolated trees by a parasitic fungus Sphaerostilbe flammea.

For several years, populations of the European pine sawfly have been controlled in pine plantations more or less routinely by aerial application of virus sprays. Recently, it was shown that the virus can be held in storage for at least five years without loss in control effectiveness.

The foliage of certain trees and the guts of certain insects that feed on this foliage appear to contain antibacterial substances. It was found that raw extracts prepared by pressing the liquid from the ground up foliage of Virginia, pitch and loblolly pines, eastern hemlock, Norway spruce, and sweet gum, inhibited the growth of Bacillus thuringiensis. When the raw extracts were centrifuged, only the supernatant fluid contained antibacterial properties. Extracts from hemlock also inhibited growth of B. cereus, B. soto, and Pseudomonas sp.

Recent research indicates that Bacillus thuringiensis var. thuringiensis may occur naturally in the western pine beetle. The bacillus also appears to be pathogenic to the mountain pine beetle.

A method was developed for testing commercially produced lots of Bacillus thuringiensis. Larvae of the greater wax moth were placed on sheets of filter paper in petri dishes on which were known numbers of spores of the bacillus. Mortality readings taken after 5 days of exposure were sufficient for determining the insecticidal activity of the material.

A species of fungus, Metarrhizum anisopliae, has been found parasitizing larvae of the black turpentine beetle in Mississippi. Its potentialities for control of the beetle are unknown.

A method has been developed, utilizing serological techniques, for detecting the presence of polyhedrosis virus in gypsy moth larvae prior to the appearance of visible symptoms. It should be especially helpful to those charged with the responsibility of determining the need for direct control of gypsy moth infestations.

c. New approaches. Fifth instar gypsy moth larvae treated with juvenile hormone extracts from gypsy moths and cecropia moths remained in this instar several days longer than normal. Further studies with these growth-regulating substances are needed before their possible usefulness in control of the gypsy moth can be determined.

Studies to-date indicate that male gypsy moths can be sterilized by exposure to gamma irradiation from a Cobalt-60 source without the production of harmful side effects. So far, it appears that irradiation of 9-day-old pupae with 20,000 roentgens is about optimum. It may be possible to secure sterilization by irradiating larvae at lower dosages but the extra care required in rearing and handling them makes it impractical to treat large numbers of them. Further research is needed on the habits and

behavior of irradiated males as a basis for determining the practicability of using them in gypsy moth control.

2. Chemical Control

Until such time as more abundant knowledge is secured on the possibilities and techniques of preventive control of forest insects through the use of biological control factors or prescribed silvicultural practices, it will continue to be necessary to apply chemical insecticides to suppress outbreaks of many destructive species in order to prevent or reduce insect-caused losses.

a. Systemics. Either one of the systemics, Di-Syston or Thimet, will control infestations of the mimosa webworm (Homadaula albizziae Clarke) on honey locust in the nursery. Application of either material to the soil at the rate of 8 lbs. per acre in a granular formulation followed by cultivation within 24 hours, provides season-long protection. Trees receiving this treatment can be baled and sold the same year. These materials constitute a hazard as long as they remain on the surface but, so far, no wildlife mortality has been observed after they worked into the soil. They are not suitable for use by the home owner.

Studies have shown that if cottonwood cuttings are dipped in 44 percent phorate dust (Thimet 44-D) before they are planted in Mississippi, sprouts will remain free of serious attack from the cottonwood borer and other insects during the first year. Trees from treated cuttings planted in 1960 averaged 16.4 feet in height by the end of the first growing season. In contrast, trees from untreated cuttings planted at the same time averaged only 12.2 feet tall and were crooked and forked, and had stunted terminals. Supplemental treatments of trees one year in place with 10 percent granular phorate applied to the soil between tree rows show promise of minimizing damage for at least the second year.

Implants of the systemic, Dimethoate, applied at the rate of approximately 4 ml. per inch of actual girth, effectively prevented development of Engelmann spruce beetle larvae in about one-half of the phloem area of the lower 30 feet of the main stem of mature Engelmann spruce trees. Applications of Di-Syston were much less effective. Irregular translocation of these materials may have accounted for the lack of complete control.

Treatment of one-year-old loblolly pine seedlings with a single application of one gram of 10 percent granulated Thimet per tree on February 20, in the Deep South, prevented tip moth attack throughout the year. Untreated check trees were readily attacked throughout the year.

b. Fumigants. The European pine shoot moth has only recently become established in the Pacific Northwest where it poses a threat to valuable

native ponderosa pine stands in the West. To curb this threat by means of quarantines and local eradication, a thoroughly effective method of treatments of infested pines is required. A crash program was undertaken to determine possibilities of killing 100 percent of the shoot moth population by fumigation of infested trees with methyl bromide without, at the same time, seriously damaging the host pines. As a result of these studies, recommendations have been issued to expedite movement of young pines under State quarantines. These include treatment of nursery trees in permanent fumigation chambers and for trees in place in the nursery.

Better control of the Texas leafcutting ant was obtained when the fumigant methyl bromide was introduced at a depth of 30 inches in the nest than at 6 inches. Indications also were that better control was obtained when a given amount of the fumigant was introduced in three holes rather than in one or two. Application of granules of heptachlor or dieldrin to the surface of nests gave unsatisfactory control.

c. Conventional sprays. Recent studies in Oregon indicate that in order to control the Douglas-fir beetle in Douglas-fir log decks by spraying, the logs should be sprayed individually before decking.

Field applications of 1.5 percent concentrations of lindane in diesel oil killed 92 percent of western pine beetles emerging from pine logs. The formulation also completely controlled infestations of the California five-spined engraver beetle. Aerial application of DDT at rates of 1/4 and 1/2 lbs. per gallon of oil per acre completely controlled infestations of the forest tent caterpillar in Alabama. A few fish were killed in areas sprayed at the 1/2 lb. rate, but no injury to fish or wildlife was reported in areas sprayed at the 1/4 lb. rate. Areas sprayed at the rate of 1/8 lb. per acre were not controlled satisfactorily. About 80 percent of the caterpillar population was killed in stands sprayed with malathion and dibrom at rates of 1 lb. per acre. Failure to secure 100 percent control was attributed to the fact that about 20 percent of the larvae were resting on the trunks of the trees, or, more simply, were not feeding. By the time these larvae became active the residual effectiveness of malathion and dibrom had broken down. Suspensions of Sevin in oil, applied at rates of 1/2 and 1 lb. per acre, were not satisfactory. DDT sprays directed against the first generation of the Nantucket pine tip moth in Maryland were effective in preventing infestation during the generation, but not during succeeding generations.

Several concentrations of dieldrin sprays were applied to pine bolts, some of which were infested with the western pine beetle, Dendroctonus brevicomis, and some with species of Ips, to determine whether surface or tissue deposits are most effective in controlling these insects. Water suspensions were used to create surface deposits; acetone solutions to create tissue deposits. Results showed the surface deposits to be most effective against both groups of insects.

Progress was made in studies of the behavior of insecticidal sprays when applied to pine foliage. Oil solutions containing DDT rapidly penetrated the cuticle of pine needles. Later the DDT reissued to the surface where it could be contacted by feeding insects. In laboratory studies of residues from pine needles sprayed by airplane at the rate of one pound of DDT in a gallon of oil per acre, no DDT could be detected for a period of 8 weeks. This suggested that control effectiveness of DDT sprays directed against defoliators of pines is secured either through direct contact at the time of spraying or later through residual stomach action. It was also found that most of the DDT residues were confined in those parts of growing needles already present at the time of spraying.

Portable mist-blowers were used effectively in New York in applying insecticides for control of the white pine weevil. Weevil damage was reduced substantially in 17 of 18 experimental study plots where pines were treated by this method both with malathion and lindane, each of which was in solution with Arochlor 5460. In other studies better protection was obtained by drenching the leaders of the pines with a hydraulic sprayer. Here, lindane gave better protection than malathion. In Pennsylvania, neither granular aldrin nor granular heptachlor gave satisfactory control of the weevil when applied in infested pine plantations. Both materials were formulated at 10 percent concentrations and applied at the rate of 5 lbs. per acre.

Progress was made in determining effective insecticidal formulations and spray schedules for controlling insect pests of flowers and cones of pine trees in the South. Properly timed applications of a 0.5 percent BHC water emulsion spray to first-and second-year cones effectively controlled attacks by Dioryetria spp. until the cones matured. Slash pine female flowers were protected from damage by the thrips, Gnophothrips piniphilus, by one or two hydraulic applications of a 0.1 percent heptachlor water emulsion. A 0.2 percent Guthion water emulsion spray was also very effective in protecting slash pine cones from attacks by species of Laspeyresia and Dioryetria, where applied in the spring.

Procedures were developed for detecting minute amounts of insecticidal residues in and on tree tissues through the use of gas chromatography. Using these procedures as little as 10^6 micrograms of lindane have been detected.

3. Biology and Ecology

Knowledge of the biology and ecology of insects is prerequisite to their control, be it either by direct or indirect methods. No two insects are alike in their life histories, habits, or behavior. No two react alike to the complex of environmental factors affecting them. No two have exactly the same feeding habits or nutritional requirements. Some have a wide

range of hosts; others are confined to single hosts. Some are even more restrictive, requiring hosts in particular degrees of vigor. Some are widespread in distribution, others much less so. Conditions conducive to outbreaks are recognized for a few species. The causes of outbreaks of others, many of which are extremely destructive, are unknown. Much of the above applies equally to the insect enemies of forest insect pests. Success in forest insect control hinges largely on the status of our knowledge of insect biology and ecology.

a. Barkbeetles. Brood development of the Black Hills beetle was fairly rapid in cabinets where the temperature was held at 70° - 80° F. and relative humidity at 80 percent. There was no development in cabinets where humidity was held at 80 percent and temperatures at 60° F. or 90° F.

In southern Utah and southern Idaho mortality of Douglas-fir beetle broods was not exceptionally high during periods of either extremely hot or exceptionally wet weather. As a matter of fact, the exceptionally wet weather appeared to be beneficial to the insect.

Developing broods of the black turpentine beetles in pine stumps in Louisiana moved downward below the duff or ground line as they became older. Stump examinations revealed that 80-90 percent of the full-grown larvae, pupae, and new adults were either in the root collar region or in the large surface roots below the ground line.

In the Pacific Northwest, heavier attacks by the Douglas-fir beetle occurred in blowdown Douglas-firs that were lying in the shade than in those lying in the sun, regardless of the ages of the trees. Highest brood survival occurred in shaded old-growth, and lightest in exposed second-growth trees. In the Southwest, treatment of living Douglas-fir trees with low dosages of ammate resulted in the creation of trees favorable to attack by the Douglas-fir beetle.

Intraspecific competition appears to be an important limiting factor affecting mountain pine beetle infestations. In Utah, it was found that the greater the intensity of attack per unit area of bark surface, the shorter the egg gallery produced per attack; the higher the brood mortality prior to adult emergence; and the fewer the number of beetles produced.

Adults of the first generation during the year of Ips lecontei prefer to breed in ponderosa pine slash in Arizona. Adults of the second and third generations are attracted to the tops of large standing pines. From 70 to 100 percent of the brood of this species were killed in sections of logs exposed to temperatures of 0° to 5° F. for 3 hours or more. Equally high percentage mortality of I. confusus broods was obtained by exposing them for 3 or more hours to temperatures of -10° to -15° F. There was little or no change in cold-resistance of either species from November to March.

Bark beetles of the genus Dendroctonus apparently can tolerate saturated resin vapors of their normal host pines but not those of non-host pines, according to studies recently made in California. Evaporates of other resins from host pines may be toxic. Toxicity of these evaporates from any single tree differs significantly at different times during the growing season.

In Oregon, epidemic mortality of Douglas-fir following attacks by the Douglas-fir beetle was evaluated effectively by aerial photography during the first year of tree killing. Both panchromatic and color films were used; however, twice as many errors in interpretation were made on panchromatic as on color films.

Studies in Idaho indicate that resin exudation pressure in Douglas-fir is lowest in the older trees. Lower pressures in the older trees may be one of the principal reasons why they are most susceptible to attack by the Douglas-fir beetle.

In East Texas, initial attacks by the southern pine beetle from May through early September occurred most often on the lower part of the trunk; after late September, first attacks usually occurred on the mid-trunk where they often found themselves in competition with Ips avulsus. When the latter species attacked at the same time as the southern pine beetle, brood survival of the latter was generally poor. In laboratory studies, more southern pine beetles were reared from bolts cut from slow-growing pines than from fast-growing ones.

b. Defoliators. In California, the pine sheath needleminer, Zelleria haimbachii, has occurred in destructive numbers in pine plantations in recent years. According to recent studies, young pines from 4-5 feet tall that are growing in the open can sustain upwards of 75 percent defoliation by the insect for two successive years without serious loss in diameter growth. Given an equal percentage defoliation of trees 25 feet tall and growing in a closed stand, diameter growth was reduced by at least one-third.

In the Southeast the elm spanworm disperses to some extent, at least, through the flight of gravid female moths. Some of the latter have been collected at considerable distances from centers of known infestations. This may or may not be the principal means of spread of this destructive defoliator.

Eggs of the Great Basin tent caterpillar have been found hatching in late May in New Mexico. Two weeks later about 80 percent of the larvae were in the third instar; and within five weeks 90 percent were full-grown. Pupation began a week later; adults emerged from early July to mid-August; and eggs were laid soon thereafter. Three weeks after it was

laid each egg contained a fully-developed first-instar larva. It was in this stage that the insect lived over winter.

Preliminary studies indicate that moderate to heavy defoliation occurs about 90 percent of the time in stands where egg mass populations of the elm spanworm are in excess of 25 in a sample consisting of 12 five-foot branches at any one location. Light to moderate defoliation can be expected in about 75 percent of the cases where the number of egg masses in the sample varies from 1 to 25.

Estimates of degree of defoliation of balsam fir in the Lake States were almost as accurate when made from aerial photographs, taken at a scale of 1:1584, as when made by observers on the ground.

c. Seed and cone insects. While several species of insects infest the cones of Douglas-fir in California, the percentage of cones infested by any one species varies widely from tree to tree. Furthermore, in general, trees supporting low populations of any one species also support low populations of the others. So far, the reason for this is unknown.

Intensive laboratory studies showed that larvae of Contarinia sp. damaged an average of 15.6 seeds per cone of Douglas-fir, or about one-fourth of the total seed complement. In these cones, furthermore, about twice as many of the undamaged seed were unfilled as were unfilled on protected cones. The reason for this was not determined. A likely cause was thought to be the failure of pollen to reach the micropyles of many of the developing seed as a result of the presence of large numbers of insect eggs.

The bug, Leptoglossus occidentalis, appears to be an important pest of the seed of Douglas-fir in California. In controlled laboratory studies, in which it was caged with Douglas-fir cones, the percentage of sound seeds per cone was reduced from 71 to 1 percent. In size and outward appearance cones that have suffered heavy attack look almost exactly like unattacked cones growing on the same tree. Until quite recently, this insect was not known to feed on the seed of this tree.

In interior Alaska, several species of insects have been found infesting or damaging the seed of white spruce. In 1960, over 5 percent of these seed were destroyed in samples collected at 60 different locations. The major insect species involved were identified as Laspeyresia youngana (Kearf.), the spruce seed maggot, Megastigmus sp., and the spruce cone-axis midge, Dasyneura rachiphaga Tripp.

d. Sucking insects. In the Pacific Northwest, Pacific silver firs and subalpine fir heavily infested by the balsam woolly aphid for 3 to 4 years have died. In contrast, grand firs have survived though heavily infested for as long as 12 years. The latter trees did not escape damage, however, since loss of hei ght growth amounted to some 40 percent. So far, the aphid has not damaged noble fir growing in the area. In the southern Appalachians, the percentage of Fraser firs killed by the aphid in a series of study plots increased from 0.5 to 8.0 percent from 1960 to 1961. During this period the number of trees infested in the plots also increased 8.5 percent. In examining fir trees for evidence of balsam woolly aphid damage, it is often difficult to determine the degree of gouting in the tops of trees. Recent studies showed that this type of damage could be identified on 70 mm transparencies taken from the air.

e. Plantation insects. Following a 5-year European pine shoot moth outbreak in the Lake States, it was determined that maximum damage had been incurred during the third and fourth year of the outbreak. In the affected plantations, from 4 to 17 percent of the young trees escaped injury altogether; also from 7 to 15 percent of them had been damaged beyond the point of recovery. Injuries to the remaining trees were of such a nature that they could be corrected by pruning. Height growth of attacked pines was not seriously impeded.

The pine reproduction weevil which has been an important pest of hard pines in plantations in California for several years was recently found for the first time to be attacking young soft pines. In the nursery of the Institute of Forest Genetics at Placerville both eastern and western white pines and their hybrid, and Mexican white pine were attacked successfully; and some killing of sugar pine reproduction in natural stands in the area was recorded. So far, there is no explanation for this sudden, if belated, attack on soft pines by the insect.

New nests of the Texas leafcutting ant in Louisiana are composed of single and almost vertical 1/2-inch diameter galleries leading down into the ground. In each gallery there are two small fungus garden cavities about a foot below the soil surface, and another small one at the end of the gallery several feet below the surface. During summer most fungus gardens are found in cavities in the upper 2 feet of nests; during winter they are found only in cavities that are at least 8 feet below the surface. During summer, fertile queens, workers, and brood occur in the upper cavities. During winter they are found only in the deeper cavities. The fungus grown by the ants has been identified tentatively as Lepiota gonglyphora, a species of mushroom. As many as 7 queens have been found in a single large nest. Flight of males and queens follows in the wake of heavy rains. During flight they are subject to predation by the nighthawk, Chordeiles virginianus.

Valid estimates of European pine shoot moth populations were made in plantations in the Lake States both during late fall and spring simply by determining the proportion of the trees, or the leaders of the trees, that were infested. Previously, it has been thought necessary to count all of the insects in a given sample.

4. Silvicultural Control

a. Barkbeetles. For twenty-four years a study has been underway in California to determine the effectiveness of sanitation-salvage cutting in old-growth ponderosa pine stands in preventing barkbeetle-caused mortality. During that time losses in treated stands have averaged 19.5 board feet per acre per year, as compared with an average of 99.5 board feet per acre in untreated stands. In 1960, beetle-caused mortality was much higher than these averages in both treated and untreated stands; but it was still almost twice as great in the untreated stands.

Since 1948, studies have been underway to determine if the system developed in California for identifying ponderosa pines that are susceptible to bark-beetle attack can be used in northern Rocky Mountain stands. So far, results are inconclusive. However, almost 80 percent of 64 trees killed to-date on study areas were in risk classes 3 and 4. This strongly suggests that the system applies in the northern Rockies; but additional records are needed to verify the fact.

b. Hardwood borers. In the upland oak type of Kentucky the red oak borer causes considerable degrade in lumber by boring in living hardwoods. Studies indicate that this damage can be reduced by poisoning trees in which populations of the insect build up and are maintained. In selecting trees for poisoning it is not necessary to look for evidence of borer attack. It suffices to select low quality trees since these are the ones most likely to be infested. Best results are obtained when these trees are poisoned during the period of July 1 of odd-numbered years to June 1 of even-numbered years.

Evidence is mounting to the effect that sparse stands of aspen in the Lake States are more severely infested by the poplar borer, Saperda calcarata, than dense stands. Because of this habit of the borer and because it appears to be successful in attacking the larger, faster growing trees in stands averaging up to 8 inches d.b.h., thinning operations would seem likely to result in an increase in damage in the residual stand. The silvicultural practice of clean cutting aspen to ensure regeneration appears to be a sound practice from the standpoint of this important pest.

c. Spruce budworm. Defoliation of balsam fir by the spruce budworm in the Lake States was reduced in study plots receiving partial cutting treatments whereby the stand density of balsam fir and spruce was reduced to about 65 square feet of basal area per acre. A possible reason for this reduction was the higher degree of parasitization of budworm eggs by the hymenopteron, Trichogramma sp. in the treated plots than in untreated portions of stands.

5. Wood Products Insects

Insects that damage or destroy wood products are a continuing problem in this country. Considerable progress has been made in past research in the control of many of these insects but losses continue to be severe.

a. Termites. Studies have been underway for several years to determine the most effective formulations and methods of application of a wide variety of chemicals as soil treatments for prevention of damage by subterranean termites to structures. To-date, formulations and dosages of each of the following have given complete protection for 12 or more years under field conditions: sodium arsenite, chlordane, aldrin, dieldrin, and BHC (alpha beta cake). Heptachlor has also performed equally well for the 9 years it has been under test.

Wooden stakes treated with 2 percent copper selenite in 1944 and 1945 and placed in the ground in Mississippi and the Canal Zone are still free of subterranean termite attack. Ninety percent control of subterranean termites for about 10 years was obtained in Mississippi by soaking wood for 6 hours in 2 percent copper naphthenate in kerosene. About 70 percent control was obtained in the Canal Zone for about the same length of time by soaking 4 hours in 4 percent copper naphthenate. A concentration of 0.125 percent chlordane, applied at the rate of 1 pint per square foot of soil surface, has remained effective against the subterranean termite for at least 5 years. Aldrin and dieldrin have been effective for at least 3 years at concentrations as low as 0.016 percent; and heptachlor has been effective for 6 years at a concentration of 0.041 percent. In each case lower concentrations were ineffective. Treatment of gravel fill with 1.0 percent chlordane has prevented termite penetration for at least 4 years. Wooden stakes pressure-treated in 1944 and 1945 by Battelle Memorial Institute with 2.0 percent copper selenite, at a retention of 0.5 lbs. per cubic foot, and placed in the ground out doors in Mississippi and the Canal Zone, are still free of termite attack.

In 1952, a study was initiated in the Canal Zone to determine the effectiveness of various preservatives in preventing attacks by drywood termite. The most effective material under test is 4 percent copper naphthenate applied as a three-hour soak. So far, it has been 90 percent effective in preventing attack. Five percent DDT plus 2 percent chlordane in No. 2

fuel oil applied by brush and 5 percent pentachlorophenol applied as a soak are also fairly effective after 10 years.

Studies in Wisconsin indicate that northern limits of outside survival of subterranean termites may be where soil temperatures at a depth of 6 inches fall to 20° F. or lower. Also in Wisconsin, two active components of fungus-infested wood that are attractive to these termites were extracted by steam distillation.

b. Powder post beetles. Both dry and green ash wood have been protected for at least 4 years from Lyctus powder post beetle attacks under normal lumber storage conditions in Mississippi by dipping it for 10 seconds to 3 minutes in any one of several different residual insecticides.

Wood can be made safe from attack and damage by lyctus powder post beetles by storing it under moist conditions with the bark intact for 3-4 months after it is cut. This permits enzymes in the wood to continue functioning long enough for it to become depleted of starch. This powder post beetle does not develop in starchless wood.

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WORK AND LINE PROJECTS, Forest Insect Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 2-e1	BARKBEETLES AFFECTING FOREST AND SHADE TREES														
-1	Sanitation-salvage			x	x										V, 4-a
-3	Engelmann spruce beetle					x									V, 1-a, 2-a
-4	Black Hills beetle					x									
-5	Douglas-fir beetle		x		x										V, 1-a, 2-a, and 3-a
-6	Southern pine beetle									x	x				V, 3-a
-7	Turpentine beetles									x	x				V, 1-b, 3-a
-8	Tree resistance to bark beetles			x											V, 3-a
-9	Improvements in chemical control			x											V, 2-c
-10	Mountain pine beetle			x	x										
-11	Ips engravers									x					
-13	Disease pathogens		x						x						
-14	Barkbeetles in Southwest					x									
FS 2-e2	INSECTS AFFECTING FOREST PRODUCTS														
-1	Powder post beetles										x		x	x	V, 4-a, 5-b
-2	Subterranean termites										x		x	x	V, 5-a
-3	Drywood termites										x				V, 5-a
FS 2-e3	DEFOLIATING INSECTS AFFECTING FOREST & SHADE TREES														
-1	Pine sawflies							x	x						V, 2-c
-2	Spruce budworm		x		x	x	x		x						V, 1-a, 4-c
-3	Black-headed budworm	x	x												V, 1-a

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
PSW - Pacific Southwest
INT - Intermountain
RM - Rocky Mountain
LS - Lake States
CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
WO - Washington - Beltsville

WORK AND LINE PROJECTS, Forest Insect Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
-4	Needle-sheath miner			x											V, 3-b
-5	Diseases of insects other than barkbeetles		x		x				x						V, 1-a, 1-b, and 3-b
-6	Parasites and predators - Miscellaneous insects							x	x						V, 1-a, 1-b, and 2-a
-7	Tree resistance - insects other than barkbeetles			x				x							V, 3-e
-8	Gypsy moth								x						V, 1-c
-9	Aerial applications													x	
-11	Lodgepole needleminer			x											
-12	Larch case bearer				x										
FS 2-e4	INSECTS OTHER THAN BARKBEETLES AND DEFOLIATORS AFFECTING FOREST AND SHADE TREES														
-1	White pine weevil								x						V, 2-c, 3-a
-2	Terminal feeding moths		x				x	x	x	x	x				V, 2-a, 2-b, and 3-e
-3	Sucking insects other than balsam woolly aphid							x	x						
-4	Insect vectors elm tree diseases							x	x						
-5	Insect vectors oak wilt							x							
-6	Balsam woolly aphid		x					x		x					V, 1-a, 3-d
-7	Seed and cone insects	x		x			x	x	x	x					V, 1-a, 2-c, and 3-c
-8	Pine bark weevils									x					
-9	White grubs									x					
-10	Hardwood borers						x	x			x			x	V, 2-a, 3-a, and 4-b

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WORK AND LINE PROJECTS, Forest Insect Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 2-e5	DEVELOPMENT OF METHODS FOR CONDUCTING FOREST INSECT SURVEYS														
-1	Ground surveys		x	x	x				x	x					V, 3-b, 3-c
-2	Aerial surveys		x	x			x		x	x				x	V, 2-b

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VI. FOREST DISEASE RESEARCH

Problem

Diseases occur in all parts of the country irrespective of land ownership, on all forest tree species, hardwoods and conifers alike, on trees of all ages from the seeds themselves to over-mature forest veterans, and affect all parts of the tree from the root tip to the terminal bud and from the outer bark to the central pith. Other forest plants important to forage, recreational, and watershed values are equally subject to attack. These diseases are caused by a wide range of biotic agents such as flowering plants, fungi, bacteria, nematodes, and viruses and an equally diverse assortment of abiotic factors such as temperature and moisture extremes, nutritional excesses or deficiencies, and noxious substances in the atmosphere. Working singly or in combination these factors may induce disease causing death, loss of growth, deformity, lowered quality, or destruction of wood already formed in forest trees. In total, they cause as much loss in our forests as all other destructive agents combined, including fire, insects, and animals. In terms of volume, this growth impact amounts annually to 5 billion cubic feet of growing stock, including 20 billion board feet of sawtimber - a loss almost equal to the annual cut of timber in the United States. In addition, many of these or other agents continue their destruction of wood products extracted from the forest to cause additional losses estimated at $300,000,000 per year.

Program

The Department has a continuing long-term program of basic and applied research directed toward the solution of forest tree disease problems and the development of means for their control. The program is a national responsibility of the Forest Service and is conducted at 9 of the 10 Forest Experiment Stations, the Forest Disease Laboratory attached to the Washington Office and the Forest Products Laboratory. Each of the Stations conducts research on a variety of diseases of especial importance in their geographic area of responsibility and may also have leadership for research on diseases of broader regional impact. The Lake States Station, for example, has primary responsibility for research on hypoxylon canker of aspen, the Central States Station for oak wilt, the Pacific Northwest for Poria root rot of Douglas-fir, the Intermountain for breeding western white pine for resistance to white pine blister rust, and the Pacific Southwest Station for research on chemical means of dwarfmistletoe control.

The Forest Service now devotes 76 professional man-years of effort to research in this area. Over one-half of these scientists are plant or forest pathologists but to provide all the talents required, especially

for more basic research aspects, biochemists, ecologists, meteorologists, nematologists, physiologists, microbiologists, and soils specialists are also employed.

This research program is carried out in cooperation with other Federal, State, and local public agencies. Oregon State University, for example, provides mensurational assistance on the study of dwarfmistletoe growth impact on ponderosa pine; the University of California works on the comparative physiology of dwarfmistletoes and their tree hosts; Montana State University is working out the life history of Elytroderma deformans; the Universities of Missouri, West Virginia, and Pennsylvania State coordinate their researches on oak wilt with the Federal program; and TVA cooperates on the study of air pollutants.

Under PL-480 authority and funds, research programs supplementing and complementing domestic ones are under way in Poland, Finland, Spain, India, Brazil, Columbia, and Uruguay; many of which are designed to disclose native pathogens of special potential threat to North American forest tree species.

Industrial forestry organizations are also actively engaged in forest disease research and cooperate with the Forest Service program by making their lands and timber available for study, providing technical consultation, and furnishing labor. Several chemical companies donate their products for experimentation; the Pabst and Upjohn Companies are especially active in this field. The latter company also conducts laboratory bioassays for research projects using their products and have made grants to the Forest Service to support research on the antibiotic control of forest tree diseases. The Department of Defense supports substantially the research on the decay of wood in use as do several other major users of wood products and manufacturers of wood preservatives. Annual outside expenditures are difficult to determine accurately but are estimated to be equivalent to one-half the manpower devoted to this project by the Forest Service.

Progress

1. Seed and Seedling Diseases

a. Phomopsis blight of eastern redcedar. This disease adversely affects survival when infected nursery stock is planted in the field. Three years after experimental plantings were established in eastern Nebraska only 58 percent of the infected plants survived in contrast to 82 percent of the non-infected plants. Blight has so far made no significant difference, however, in either the height or diameter growth of those that do survive. A cultural study of the causal fungus, Phomopsis juniperovora, showed that vegetative growth, spore germination, and germ tube development were best at 75° F.

b. Fungicidal control tests. Fusiform rust of southern pines has not yet been controlled in Southeastern nurseries by antibiotic treatments. Phytoactin and several derivates of Acti-dione were variously applied as seed soaks, seed pellets, soil drenches, top dips, and foliar sprays. Inoculations of treated seedlings with the fusiform rust fungus gave infection rates as high as on the untreated checks.

Hydraulic spraying of slash and longleaf pines with ferbam gives excellent control of cone rust in the Southeast. A regular 5-day spray schedule during flowering season is recommended for the most positive control under varying climatic conditions.

Candidate fungicides for damping-off control were tested by pelletizing them on ponderosa pine seeds. Germination results in sterile sand in the greenhouse at temperatures not above 80° F. at Lincoln, Nebraska showed no significant differences between untreated seed and those pelletized with Dexon-PCNB (35 percent-35 percent) at a rate of 0.3 grams per 18.0 grams of seed, or with Arasan-75 applied at a rate of 2.4 grams per 18.0 grams of seed. Where temperatures sometimes reached 100° F., however, Arasan-75 treated seed had significantly lower germination than the untreated checks.

In the Northeast, black cherry seedlings treated with semicarbazone 221 and Cyprex at 14-day intervals developed significantly fewer Coccomyces lutescens leaf spots than untreated checks, though neither was fully effective.

c. Soil treatment. Vapam was compared with standard methyl bromide fumigation on large areas in several nurseries in the Southeast. Vapam was injected into the soil at 50 gallons per acre (one-half the usual rate) and covered with a plastic sheet for 24 hours. Weed control and seedling growth was equal to or superior to that obtained by the standard methyl bromide treatment and the cost was slightly less. The only disadvantage of using Vapam is the 2-week waiting period necessary before planting, compared with the 2-day methyl bromide waiting period.

Eptam at the rate of 6 pounds per acre active ingredient continued to give good weed control in large scale studies in the Southeast. Weeding time was reduced by as much as 75 percent. Eptam is now being recommended for use in forest nurseries.

Second-year results from Trizone soil fumigation at the Bend (Oregon) Nursery were slightly less promising than the previous year. Seedling stands in the fumigated beds remained significantly better but the differences in seedling heights did not persist. Differences between 140- and 200pounds-per-acre applications were not significant.

Soil fumigation in the Forest Service nursery at Placerville, California in 1961 nearly doubled the production of 1-0 stock. Outplantings of Douglas-fir grown in fumigated and non-fumigated nursery beds showed from 40 to 83 percent better survival of the fumigated stock. Soil fumigation is being initiated this year in all Federal and State forest tree nurseries in California.

d. New seedling diseases. New finds during the year included a leafspot of Magnolia grandiflora caused by Cercospora magnoliae in a South Carolina nursery. The fungi Fusarium spp. and Selerotium bataticola and the nematodes Hopolaimus and Longidorus spp. are all involved in a root rot found in a young slash pine plantation. Western-X virus was found to be widespread and causing considerable mortality to chokecherry in windbreaks and native stands in Nebraska. The needles of lodgepole pine seedlings in the Forest Service nursery at Coeur d'Alene, Idaho were heavily infected with an Alternaria-Stemphylium complex, but pathogenicity of the fungi has not been proved.

2. Root Diseases

a. Fomes annosus root rot. This increasingly important disease is being studied on white, loblolly and slash pines in the Southeast and South, on red pine in the Northeast, on shortleaf pine in Missouri, and on varying conifers in California.

In a Southwide Fomes annosus survey overall damage figures ran fairly low, 2.8 and 2.2 percent of trees dead or dying on loblolly and slash pine plots, respectively. There were some areas, however, where losses ran as high as 30 percent or more of the residual trees dead or dying from annosus root rot following thinning. Mortality was higher in planted stands and on plots on former agricultural land than in natural stands and on land that had always been forested. Damage generally increased with increased years since thinning and with increased frequency and number of thinnings. Plots with coarser textured soils and deeper A horizons tended to have more damage than plots with heavier soils and thinner A horizons. There was more annosus killing on slopes than on flats, and on plots with a deep accumulation of litter in contrast to those with little or no litter. Supplemental observations in the South suggest that in deep litter areas, attack was somewhat more severe on the less acid soils.

Creosoting newly cut stumps when thinning red pine on the Harvard Forest, Massachusetts, showed this significantly to reduce Fomes annosus infections. Fruiting bodies were later found on 24 untreated stumps and on only 7 creosoted stumps and 4 of these were judged to have resulted from secondary spread from adjacent trees rather than from primary invasion.

No standing trees on the Harvard Forest killed by poisoning with sodium arsenate in 1957 have been invaded by Fomes annosus so far. This is

highly significant when compared to thinning by cutting and not treating the stumps. Thinning by poisoning may be a means of preventing primary invasion of F. annosus into conifer stands but there are possible adverse effects that need also to be studied. Further research along this line has been started in loblolly pine plots on the Eastern Shore of Maryland where killing trees with 2, 4, 5-T is being compared with creosote and urea stump treatments as preventive measures.

In red pine spacing and thinning plots on the Fox Forest, New Hampshire, all Fomes annosus infections have been on stumps of live cut trees; no infections have been found on stumps of trees that were dead at time of cutting.

Effective control of Fomes annosus in the Institute of Forest Genetics Arboretum at Placerville, California was obtained by soil fumigation with methyl bromide. In all, twenty-eight pine species or hybrids were found infected, none of which showed any evidence of resistance. Studies on the genetics of F. annosus show that this fungus is highly variable and unstable. Isolates grown in creosote atmosphere have shown a high tendency to mutate. These mutants later were found capable of infecting wood blocks heavily coated with creosote.

Annosus infection centers were found in 80 percent of the thinned plantations and 59 percent of the thinned natural shortleaf pine stands examined in Missouri. The effectiveness of creosote, pentachlorophenol, and urea as stump treatments to prevent annosus infection is under study.

b. Armillaria mellea. The abundance of fruiting bodies found at the bases of western redcedar trees released in Idaho in 1940 indicated that root rots might be the cause of their decline. The root systems of 48 trees were excavated in 1961 to study the incidence of root decay fungi in released and non-released understory trees. One-half of the sampled trees were on plots where the understory redcedar trees were released in 1940 and the other on undisturbed plots. Released trees had responded initially by increased growth and vigor, but between the fifth and tenth year after release started progressively to decline in growth and vigor. Of the 93 basidiomycete isolations obtained from the redcedar roots, 34 cultures were of A. mellea, the only known root pathogen isolated.

Root rot caused by Armillaria mellea continued to kill 16-year-old lodgepole pines in study areas in Colorado. Losses to date total about 10 percent of the trees but there are indications that the annual mortality rate is decreasing. Tests to control the disease with Acti-dione and phytoactin were inconclusive after one year.

c. Poria weirii. Clonal distribution patterns continue to indicate that current root infections in Douglas-fir stands in the Northwest stem primarily from infected residues of previous stands. Preliminary results of a study of the survival of P. weirii in small buried wood residues show that zone lines formed within the residues are associated with long-term survival of the fungus. Several fungi isolated from these residues were found to have fungistatic effect on P. weirii. Microscopic examination of small Douglas-fir roots attacked by the fungus indicates that the thin cork layer offers little protection. Hyphae extending from the dense fungus mantle surrounding the root readily penetrate all root tissues.

d. Mycorrhizae. Fungal symbionts have been isolated directly from mycorrhizae of shortleaf pines in Georgia. Over 125 cultures, including over 30 different species of basidiomycetes, have been isolated. In some instances, two different mycorrhizal fungi have been recovered from the same mychorrhizal root. Several additional mycorrhizal fungi are under study for antagonism to Phytopthora cinnamomi, the fungus causing the littleleaf disease of shortleaf pine.

e. Littleleaf of shortleaf pine. The 10-year-old planting at Athens, Georgia, made up of 16 clones of shortleaf pine selected for apparent resistance to littleleaf disease, has reached a stage of maturity permitting the start of breeding work. Over 1,500 controlled pollinations were made in 1961, representing 64 combinations between the various clonal lines. Seedlings derived from these crosses will be assayed to determine if crossing resistant parents intensifies resistance to the littleleaf disease.

f. Other root rots. Polyporus lucidus has been found associated with root mortality of mimosa and sweetgum in the South and Corticium galactinum is associated with white oak mortality in Arkansas. Two surveys in the Southeast disclosed two species of spiral and one species of sheath nematodes in the soils of both littleleaf diseased and healthy stands, but populations were much higher in the diseased stands. No correlation was found between any nematode species and annosus root rot incidence.

3. Stem Diseases

a. Native rusts of conifers. Fungi in this group are major causes of loss in the West but even their taxonomy and host relations are not yet fully clarified.

Spruce broom rust alternation to Arctostaphylos uva-ursa and A. patula was confirmed by greenhouse inoculations at Fort Collins, Colorado. Peridermium coloradense is thus shown to be a synonym of Chrysomyxa arctostaphyli. Collections on A. patula in Arizona indicate that this manzanita serves as alternate host south of the range of A. uva-ursa.

Limb rust of ponderosa pine was transmitted to Castilleja spp. by inoculation with aeciospores of Peridermium filamentosum from ponderosa pine in the Front Range in Colorado and in the Black Hills, showing that in these areas this rust is heteroecious (in contrast to reports from further West). Several attempts at aeciospore inoculations on pine have produced no infection.

Young Peridermium stalactiforme infections on small lodgepole pine saplings were apparently killed when sprayed directly with the antibiotic cycloheximide or its semicarbazone derivative in 1960 tests in the Intermountain area. Similar apparent success was also obtained by basal stem treatment of small lodgepole pine saplings infected with Cronartium comandrae when using either the semicarbazone or methyl-hydrazone derivates of cycloheximide. None of the antibiotics cycloheximide, semicarbazone, or phytoactin have yet been successful in controlling Peridermium harknessii gall rust or Coleosporium solidagninis needle rust of lodgepole pine when applied as aerial sprays.

b. White pine blister rust. Basal stem application of antibiotics for control of the rust on sugar pine is undergoing large-scale field trials. The Pacific Northwest and Pacific Southwest Stations and Regions 5 and 6 are cooperating in this study that covers the range of the species in Oregon and California. Fall treatments have been applied according to plan on 14 areas on 5 National Forests. Results to date of older studies in California show that a high percentage of directly treated white pine blister rust infections on sugar pine can be killed by spray application of cycloheximide, orthophenylphenol, or pentachloronitrobenzene in light petroleum oil. The antibiotic phytoactin shows promise as an aerial spray.

Antibiotic control of white pine blister rust on eastern white pine shows encouraging preliminary results when evaluated according to a new canker necrosis scale, from trials by basal stem and aerial applications in the Lake States. A large-scale study, comparable to the sugar pine study in the West, was initiated in that region in 1962. In the Southeast, by contrast, all tests of antibiotics on eastern white pine have so far given only negative results.

In the program at Moscow, Idaho of breeding white pine for resistance to white pine blister rust, 125 new canker-free candidates were found during the year, bringing the total of such natural selections to almost 350. This year for the first time a small amount of F_2 seed was collected from F_1 seedlings which flowered in 1960 when only 10 years old. Fifteen of 25 white pine interspecies hybrids attempted in 1960 gave sound putative hybrid seed. Twenty-eight new hybrids were attempted in 1961 and so far none of the pollinations have failed. Resistance tests now in use are based on four single-cross test crosses, and F_1 progenies therefrom. Mixed-pollen crosses are now being tested for general combining ability of new parents. Four-pollen and ten-pollen mixes were used for test crossing of

11 new trees; the four convential single-crosses were made on the same trees at the same time. Progeny tests will be used to determine reliability of the mixed pollen crosses in uncovering general combining ability of 11 parents.

Inoculations of bushes exposed only to dew during the months of June and July resulted in teliospore production and sporidial discharge demonstrating that dews developing along valley bottoms in the Inland Empire provide enough moisture for the maintenance and development of the rust on ribes.

c. Fusiform rust. Development of this disease on slash and loblolly pine has been recorded in 5 plantations and 3 natural stands in the South during their first 16 to 29 years. Forty-three to 90 percent of the trees became infected; mortality ranged from 10 to 52 percent; and, except for 2 dense natural stands, only 13 to 37 percent of the original trees were rust-free or with non-dangerous infections and suitable for crop trees. Most stem infections originated on branches and the fungus grew faster and farther in branches of loblolly than slash pine. In both species most branch infections originating more than 10 inches out died before reaching the stem.

The preponderance of evidence to date, from the South and the Southeast, is that the cycloheximides, in the formulations used as basal stem applications, have no value in controlling fusiform rust. Some indications of control have been noted when cycloheximide was applied at 250 ppm in diesel oil directly to cankers which had been slit.

One hundred and eighty seedlings from each of 3 types of slash x slash pine crosses were artificially inoculated with Cronartium fusiforme aeciospores. Progeny from rust-free parents were significantly more resistant to fusiform rust than progeny with one or both parents rust infected. Variability was high among progeny from rust-free parents. Similar inoculations of progenies from 4 slash x shortleaf, 1 shortleaf x slash, and 1 shortleaf x loblolly crosses resulted in gall formation in 4 to 92 percent of the progenies. The high infection rates were associated with an individual shortleaf parent. Rust resistance in shortleaf hybrids appears to be more complicated than the simple dominance for resistance previously reported.

d. Canker diseases. A canker disease of yellow-poplar in the Central States was determined to be caused by Fusarium solani, in this case a pathogen of opportunity causing damage only during periods of drought. This same fungus has been consistently isolated from tupelo lesions in the South and inoculations there produced cankers on 1-year-old tupelo. It has also been isolated from trunk cankers on 10-to20-year-old cottonwood in the South where infection was associated with severe flooding.

The pine pitch canker fungus was found fruiting on living host tissue for the first time in the Southeast. Following artificial inoculations, the fungus rapidly girdled and subsequently sporulated on Monterey pine. This evidence that sporulation can take place in nature on specific hosts may give definite leads as to its natural means of transmission.

In studies of genetic resistance to chestnut blight, chestnut scionwood accessions were received from over 100 locations and about 1,800 scions were distributed to 65 cooperators in the 12 northeastern States. In a similar program in the Southeast scion material was collected from six new, presumably blight-resistant American chestnuts and grafts made. If all grafts succeed, 9 clonal groups will be under test by exposure to blight infection in an area near Asheville, North Carolina in order to detect and perhaps intensify resistance to this disease. Fifty-nine chestnut seedlings that had been treated with colchicine were planted on a permanent site in Pennsylvania for future observation and study and to serve as a future source of tetraploid grafting wood for perpetuation and experimentation. The possibility of controlling chestnut blight with antibiotics is also being studied in the Northeast.

e. Dwarfmistletoes. In the growth impact phase of the study of the economics of dwarfmistletoe control of ponderosa pine in the West, field work was confined to a single young sawtimber stand in Oregon that most nearly filled the exacting study requirements. Preliminary analyses of some of the data clearly show a marked reduction of both height and diameter growth associated with severe infection and that infection is correlated with increased mortality. Percentage of crown broomed appears to be a better measure of infection in relation to growth impact than systems previously devised. Field work was also completed on a related study in old-growth ponderosa pine, also in Oregon, and results were in general agreement with previous reports, i.e., higher mortality in badly infected parts of stands and lower height/d.b.h. ratios in badly infected individuals.

Growth impact studies made in 25 Colorado lodgepole pine stands ranging from 50 to 150 years old show that length of time the stands have been dwarfmistletoe infected and stand age have a marked effect on the amount of damage caused by the parasite. Reduction in height and d.b.h. of dominant and codominant trees averaged 0.7 percent per year since time of infection while reduction in total and merchantable volume per plot averaged 1.3 and 1.9 percent per year, respectively. Healthy 100-year-old stands had an average merchantable volume of 2,300 cubic feet per acre but stands of the same age infected for 70 years average but 300 cubic feet.

A study of the last 10 years of growth on increment cores taken from Douglas-fir and western larch sawtimber trees in eastern Washington and northern Idaho showed (1) that light dwarfmistletoe infection had no effect on recent diameter growth of western larch, a slight effect on large sawtimber (+16" d.b.h.) and a moderate effect on small sawtimber (11"-16" d.b.h.) Douglas-fir, (2) heavy infection materially reduced diameter growth, more so in Douglas-fir than in larch, and (3) heavy infections reduced diameter growth less in small sawtimber than in large; the reverse was true in lightly and moderately infected trees. The magnitude of the growth losses was in the order of 1/2 to 2/3 for heavily infected trees.

Analysis of the endophytic system of 170 infected lodgepole pine branches in the Southwest indicated that for branches less than 2 inches in diameter, the infection can be removed by pruning off the branch flush with the bole if dwarfmistletoe shoots or basal cups do not occur closer than 4 inches to the bole.

In California light was shown to have no effect on germination of dwarfmistletoe seed but controlled greenhouse tests, using pregerminated seed of dwarfmistletoe placed on Digger pine, show that partial shade is the most favorable for establishment of the parasite. Either high or low light intensity markedly reduced infection.

In the greenhouse at Moscow, Idaho, dwarfmistletoe plants are being produced on tree seedlings in 10 to 12 months after the seeds are placed on the host. A western larch seedling four months old was successfully inoculated with dwarfmistletoe seed. Aerial shoots were produced when the seedling was but 14 months old and the parasite killed the seedling when it was but 17 months old. This indicates the susceptibility of seedlings and tissues less than a year old, the rapid development of the parasite under favorable growing conditions, and its lethal effect on such seedlings.

Field and greenhouse observations of western larch infected with dwarfmistletoe reveal that when activity is resumed in the spring following the dormant period, growth begins in infected branches 8 to 14 days prior to growth initiation in non-infected branches. This is suggestive of the functioning of growth regulators and paper chromatography is being used to study the production, concentration, and identification of growth regulators involved in the host-parasite relationships. Foliar applications of radioactive phosphorus (P^{32}) have proven highly satisfactory for studying translocation in the host-parasite complex.

The results of 1959 and 1960 tests on the chemical control of dwarfmistletoe on pines and true firs in California were checked and 39 new tests were made on 496 trees. Results show that branch and bole infections amenable to direct treatment can be killed by prescribed dosages of phenoxy weed-killers formulated in light petroleum oil.

f. Heart rots. Fifteen plots with trees 80- to 115-years-old and 7 plots 30- to 50-years-old were clear cut in even-aged stands of the oak-hickory type in southeastern Ohio and the trees dissected for decay determinations. Decay losses averaged 4.4 percent in the older stands and .04 percent of the gross volume in younger stands. A partial analysis of the data showed that for black, chestnut, and white oaks the lowest percentage of volume decayed was in the largest trees. Black oak has more decay on the poorer sites while white oak has more decay on the better sites. Chestnut oak was intermediate, having more decay on medium than on either poor or good sites.

Analyses of data from upper-slopes in Oregon showed that Echinodontium tinctorium, alone or in mixture with Pholiota adiposa, was responsible for about 40 percent of the total number of heart rot infections and 74 percent of the cubic and board-foot volume loss in white fir. About 75 percent of the total number of Echinodontium infections appeared to have entered the tree through dead branches and branch stubs. Eighty-three percent of all trees infected by this fungus had one or more conks. Detailed analysis of all such conks found on white firs on all plots made it possible to develop these crude guidelines for cruisers:

Cull all conk-bearing white fir less than 19" d.b.h.
Cull all trees over 19" d.b.h. when the distance between the lowest and highest conk is over 15 feet.
For trees over 19" d.b.h. and with a distance of 0 to 15 feet between the lowest and highest conks, apply a flat cull factor of 65 percent

Studies of E. tinctorium in culture at the Spokane laboratory are concerned with temperature, humidity, and nutritional requirements for optimum growth. The greatest response of the fungus to date has been to certain nucleic acids. At certain temperatures, relative humidity seems to exert a much greater effect on growth than the variation in temperature itself. Previous growth-response studies in California determined terminal optimum temperatures for regional isolates of this fungus.

Periodic examinations of 100 fire-charred hardwoods in the South over a period of seven years showed that size of wounds can be predicted from the bark area charred, thus permitting the prediction of decay progress. The data also showed that age of past fire scars can be estimated from the amount of bark adhering, degree of bark cracking, and presence of conks of decay fungi.

Logging slash in Delta cottonwood stands reaches a low fire danger point in three years; slash of other bottomland species takes six years. Topwood should be salvaged within six months; after one year it usually has little value.

One hundred and fifty trees over 6" d.b.h. were dissected to determine the importance of logging injuries on New England hardwoods. Species of Hypoxylon were the principal fungi associated with sapwood decay and discoloration and stromata of these fungi were common on the wound faces. Other fungi apparently causing discolorations were frequently associated with bacteria in the tree and still others were associated with discolorations around the rot columns. The size of wounds is not as important as the appearance of wounds when considering the possible amount of decay present in the tree. Large wounds infected with Nectria sp. had very little or no decay behind them.

Decays present in northern hardwoods of sprout origin were also studied in the Northeast through dissection of clumps of sprout red maple. Polyporus glomeratus was found in many trees on certain sites and Hypoxylon sp. was frequently associated with the discoloration around the resultant rot column. Old branch stubs were more important than old stump wounds as infection courts for the fungi causing decays and discolorations.

In Colorado dissection of 113 aspen trees with Fomes ignarius sporophores showed that decay extended for an average of 12 feet above and below the highest and lowest conks. No consistent relationship was found between extent of decay and tree age, sporophore size, or number of sporophores. The height of the highest sporophore, however, provided a reliable estimate of decay; the higher the sporophore, the greater the cull percent in either board or cubic feet.

Studies at the Beltsville Forest Disease Laboratory disclosed that Stereum taxodii, recently described from Taxodium distichum in the Southeastern United States, also occurs on Cryptomeria japonica in Japan. Collections from Torreya nucifera and Chamaecyparis formosensis in Japan and C. formosensis in Formosa also appear to be Stereum taxodii.

Over 600 cultures were received from all sources during the year at the Beltsville Laboratory for identification. Of these, 283 have been identified and reported on. In response to requests, 47 cultures were sent out in-Service, 124 to others in the United States, and 55 to foreign agencies or individuals. Additions to the Reference Collection included 197 dicaryotic and 890 haploid cultures. Over 200 additional collections, including 16 new species, were added to the fungus herbarium.

4. Foliage Diseases

a. Elytroderma needle blight. The incidence of this disease of ponderosa pine has decreased markedly in eastern Oregon during the last two years, probably because of exceptionally hot summers. Many infected axes have died but many infected branches have also become symptom-free while still living. All experimental applications of antibiotics, both as basal stem treatments and as foliar sprays, to control this disease have yielded negative results, in the Intermountain area as well as in the Pacific Northwest. Studies in Montana have demonstrated the perennial nature of infection; the only part of the life cycle yet to be determined is the function of the imperfect stage and proof of which stage is the spore source of new infections. Radioactive tracers have been used to show that the so-called hyperparasite Stemphyllium is not parasitic upon the sporocarps of Elytroderma deformans but instead is saprophytic in the necrotic mesophyll layer of the infected host needles.

b. Brown spot of longleaf pine. Control of this foliage disease is possible by various spray treatments. Bordeaux is most effective as a protectant on new needles; it significantly reduces spore discharge but only slightly reduces the viability of the fungus inside the needles. In small-scale field trials in the South, semicarbazone (25 and 50 ppm) was superior to methyl hydrazone in controlling brown spot but neither antibiotic was as effective as Bordeaux. Airplane applications of these same two antibiotics, both as dusts and in oil emulsions, were ineffective at the rates and under the conditions applied. Laboratory studies of the causal fungus, Scirrhia acicola, showed that it can use various sources of nitrogen and carbon; needs added thiamine for best growth, and grows best at pH 5.8.

c. Emergence tipburn of eastern white pine. In the Southeast atmospheric ozone appears to be a cause of tipburn. When natural air was filtered into chambers through activated carbon to remove ozone, emergence tipburn susceptible graft ramets growing in the chambers were protected from injury. Similar ramets growing in non-filtered air developed symptoms of the disease. The high disease incidence in the unfiltered air chamber was correlated with high levels of atmospheric oxidants, as recorded by a commercial oxidant recorder.

d. Post-emergence tipburn of eastern white pine. This is another physiogenic disease being studied in the Southeast and the first phase of a biological indicator test for air pollutants has been completed. Both resistant and susceptible graft ramets were exposed in an area where air pollutant damage was suspected. After 6 months' exposure, all susceptible ramets had typical symptoms of post emergence tipburn while resistant ramets remained healthy. Both susceptible and resistant ramets placed in an area free of air pollution were unaffected.

Candidate trees, both highly susceptible and highly resistant to each of the above two diseases, have been located and clonal lines established by grafting from both types of trees. Breeding areas have been established for this material so that studies can be carried out to determine inheritance of resistance and susceptibility.

e. Chlorotic dwarf of eastern white pine. In Ohio various grafting experiments, using diseases and healthy white pine and healthy Scotch pine material, have largely ruled out the possibility of this disease being virus caused. Fertilizer trials, including organic chelates, are in progress to determine possible nutritional relations and other studies are exploring the role of needle fungi, premature defoliation, and genetics in this complex disease.

f. Miscellaneous foliage diseases. In the Intermountain region a definite correlation was found between summer precipitation and the incidence of the white pine needle cast, caused by Hypodermella arcuata during the subsequent summer. A species of Lecanosticta has also been found in constant association with this disease but it is not the same species causing the brown spot of longleaf pine in the South. Naemacyclus niveus on browned needles of ponderosa pine and Rhyzothyrium abietis on needles of grand fir represent new host-fungus records for north Idaho.

5. Systemic Diseases

a. Oak wilt. A number of foreign countries have placed embargoes on the importation of oak logs (and lumber) from the known infected area in the United States lest the disease be introduced into their forests. Lumber kiln-dried to a specified low moisture content is no longer a hazard and is acceptable by foreign countries. But since kiln drying of whole logs is not feasible, studies have been made in the Central States to develop other means of sanitizing oak-wilt-infected logs. A number of commercial sized oak logs were cut from diseased trees, divided into two piles, one of which was exposed to methyl bromide fumes under a plastic sheet and the other pile non-treated. Results of this first test are very encouraging but the recovery of suspect oak wilt fungus from but one spot in one of the treated logs has dictated the need for another more refined test in 1962.

Studies of the effectiveness of oak wilt control methods practiced by various States are now in their fourth year. The two study counties and the 120 plots established in Kentucky were re-surveyed. Oak wilt has spread on an average of 26 percent of the plots in the control county and on 22 percent of the plots in the county where there has been no attempt at control. The average number per year of active infection centers per 100 square miles of forest area is 23 for the control county and 29 for the non-control county. Thus no beneficial results from the control efforts are yet apparent.

All previously known oak wilt centers in the two-county study area in Tennessee were also re-examined as were the 102 centers under observation elsewhere in the Southeast for several years. In the control county, 16 percent of the centers were reactive, in the non-control county 18 percent. These results, as well as those from the two-county survey and the control plots indicate that present efforts in that area are not giving a satisfactory degree of control.

An aerial survey of part of the Nicolet National Forest in Wisconsin disclosed but one infection center, but this represented a rather substantial northward extension of oak wilt in the area.

A study in the Southeast of the effectiveness of aerial observers in detecting oak wilt showed that about 72 percent of the centers are seen. Over the past four years this figure has varied only slightly, indicating a constant level of survey reliability.

b. Oak decline. Drought appears to be a terminating factor, not an initiating factor. Analyses of precipitation and soil moisture deficiencies in the Northeast indicate that summer droughts are common in the Appalachian region and that the downward trend in radial increment of declining oaks began prior to the time of more extreme droughts, but that mortality occurred in conjunction with extreme droughts.

c. Sweetgum blight. Since 1958 it has been on the decline on seven of the plots established in the East to follow the progress of the disease. On three other plots the disease is still active but is not advancing rapidly and no longer acts as a serious threatening disease. Experimental thinnings and bi-monthly watering at the equivalent of six inches above normal rainfall have so far resulted in no noticeable recovery of blighted sweetgum.

d. Maple blight. No spread was noted during the year and trees in the affected areas in Wisconsin continued to recover. No primary pathogen has ever been found associated with blight. The conclusion is that the blight was the result of severe insect defoliation combined with freezing injury to buds that were not hardened off in the fall because of a late reflush of growth following the insect defoliation. Evidence was obtained during the year indicating that below normal precipitation results in an increase in the severity of maple blight symptoms.

e. Pole blight of western white pine. This is another disease that appears to be definitely related to past drought conditions. Detailed analyses of 70,000 annual rings on increment cores extracted from healthy and diseased white pine in north Idaho showed that the depression in growth resulting from the drought of the late 1930's was the most severe in magnitude and duration experienced in the last 300 years. A good correlation between tree growth and the continuous weather records available from 1911 at

the nearby Priest River Experimental Forest supports the hypothesis that previous droughts of similar magnitude have not been experienced by even the oldest white pine stands.

6. Decays of Wood and Wood Products

a. Decays of killed timber. The second 5-year periodic examination was completed of Engelmann spruce stands killed 20 years ago by barkbeetles on the White River and Routt National Forests in Colorado. Losses due to decay in standing trees and to windthrow now total nearly 40 percent of the original cubic foot volume. Sap rots have accounted for a progressively larger part of the total rot loss. Volume of butt and trunk rots declined between 15 and 20 years, presumably because the most decadent trees are most subject to windthrow. Windthrow is now the primary cause of loss in these dead stands and will continue to be a progressively more important factor in the future.

b. Decay of raw products. A comprehensive study of southern hardwood pulpwood stored in chip form found that gum chips, in contrast to pine chips studied earlier, deteriorated more rapidly. Oak chips tended to deteriorate slower than gum and at about the same rate as pine chips. Damage was largely concentrated in the outer few feet of all piles; chips in the deep interior of the piles were only discolored by chemical action, bacterial action, or both. Soft rot organisms were the principal causes of damage, but decay caused by typical wood-rotting fungi (white rots) was present in all piles and was much more common than encountered earlier in piles of southern pine chips.

c. Decay of wood in use. Of the ammunition boxes exposed for nine years at Madison, Wisconsin, only the boxes stored off the ground were mostly still serviceable; some variation in their condition apparently was correlated with preservative treatment but differences in soundness of dip-treated boxes generally were small.

Continued work at the Forest Products Laboratory on the verification of species identity of soft-rot isolates showed that no single nutrient salt, sugar, or nitrogen compound, or mixtures of these among a substantial number tested promoted soft rot in coniferous woods. Attack was facilitated in pine sapwood, however, by artificially maintaining a high moisture but not too low oxygen condition, and by placing a transverse section of the test block in contact with the fungus hyphae.

Trials, one to three years old, by the Forest Products Laboratory, of in-place preservative treatment of exterior building parts, being conducted at three naval establishments, do not yet show significant differences in soundness between treated and untreated units. In trials during the year, penta grease showed considerable promise for in-place treating of joints

constructed of 2 x 4-inch lumber; limitations were indicated for effective treatment of joints of larger lumber. Penta grease penetrated several inches in pine sapwood and Douglas-fir heartwood when applied directly to end grain, which indicates value for preassembly application in protecting terminal segments of large wood members.

Laboratory studies in the South showed that surprisingly good coverage of end and lap joints can be secured by brushing or spraying siding in place with water-repellent preservatives. Practical field application to buildings, however, gave highly variable results. Until more is known such applications should not be relied on to protect fully exposed walls. In-place applications failed significantly to reduce paint peeling where thick paint films existed; good protection occurred only where thick paint was first removed to the bare wood. With fully exposed experimental panels the only complete protection of siding from rain wetting was afforded by a 3-minute dip in a water-repellent preservative prior to siding attachment.

In the South exposure of full-length matched siding panels under the eave of a full-size roof showed that the addition of eave gutters reduced the amount of rainwetting of siding with 4 and 8 inches of roof overhand. A 20-inch overhand gave adequate protection without gutters but gutters still are justified for other reasons under some circumstances. After 18 months' exposure the effect of gutters and roof overhang are measurable in terms of paint peeling, molding, and staining, as well as of wood moisture content.

Three studies in the South terminated after 18 to 20 years' exposure showed that dips of 15 minutes or longer in 5 percent pentachlorophenol were almost completely effective in preventing decay. Copper naphthenate (0.5 percent Cu) was appreciably less effective and 0.2 percent pehnyl mercuric oleate was ineffective. Brush treatments, although worthwhile, were significantly less protective. A non-toxic joint sealer was less effective than brush treatment with a toxicant.

More than 12,000 moisture readings in over 1,000 houses were taken in two years to complete a cooperative survey conducted by the Forest Products Laboratory and the Southern and Southeastern Stations. The moisture readings and inspections for decay disclosed no large decay hazards except for exterior millwork exposed to rain wetting. Decay was sporadically troublesome in sub-flooring beneath shower areas. Winter condensation in crawl spaces was found in the colder climates but with surprisingly little associated decay.

At the Northeastern Station 20 of their 30 experimental basementless houses, with ground covers, were inspected for wood moisture content in subfloor timbers. Moisture averaged 14.5 percent, indicating that ground covers are still serving as effective barriers.

A survey of buildings on the Atlantic and Gulf Coasts from Charleston, S. C. to Corpus Christi, Texas, disclosed enough condensation associated with air conditioning to necessitate its consideration in the design, maintenance, and operation of buildings. Most damage occurred in floor structure but occasionally also in walls. To prevent important condensation maintain a dry crawl space; if feasible use daytime cooling only; with continuous cooling keep minimum temperature above 75° F.; where low temperatures are needed, use a vapor barrier.

d. Natural durability. The main survey of fungi-toxicity in extractives from wood, a cooperative project between the Forest Products Laboratory and the California Forest Products Laboratory, showed that methylation of tropolones from incense cedar caused them to lose fungi toxicity. This indicates one way in which decay resistance is reduced in the tree as the heartwood ages. When reacted with copper, a natural mixture of the tropolones gained considerably in toxicity. Soil block tests indicated that kiln drying, and air plus kiln drying, reduced the decay resistance of heart redwood by a small amount. Kiln drying involving presteaming and solvent seasoning tended to reduce the resistance from its normal class of "highly resistant" to "resistant".

e. Fungicidal properties of wood preservatives. The Forest Products Laboratory found a number of bacterial species isolated from diverse but very wet environments to be capable of causing increased porosity and some weight loss in both hardwood and softwood specimens. One of the isolates was identified as a species widely distributed in nature. Measurements of carbon dioxide evolution aided in evaluating the overall wood destruction. Significant losses in weight of unaltered wood by bacteria represent a rather revolutionary finding that has justified rechecking the validity of the experiments.

Four soft-rot fungi were found to alter an arsenate-chromate fluoride preservative mixture in pine and gum wood, making the wood more susceptible to decay by a Basidiomycete fungus. The preservative used is a standard water-borne treatment that is widely employed. Such organism inter-relationships have been suspected as possibly important factors in the performance of wood treated with different preservatives.

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WORK AND LINE PROJECTS, Forest Disease Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	[1] Research Locations During Year													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 2-d1	DISEASES OF FOREST TREES														
-1	Foliage diseases		x		x	x			x	x	x				VI, 1-b, 1-d, 4-a, 4-b, & 4-f
-2	Rust of conifers		x	x	x	x	x		x	x	x				VI, 3-a- 3-c
-3	Cankers					x	x	x	x	x	x				VI, 3-d
-4	Diebacks and wilts						x	x	x	x					VI, 5-a, 5-d
-5	Dwarfmistletoes		x	x	x	x									VI, 3-e
-6	Stains and decays		x	x	x		x	x	x		x			x	VI, 3-f
-7	Root diseases		x	x	x	x		x	x	x	x			x	VI, 1-c, 2-a, to 2-f
-8	Noninfectious diseases		x	x	x					x					VI, 4-c- 4-e
-9	Foreign diseases								x						
-10	Slash decay										x				VI, 3-f
-11	Genetic resistance			x	x		x		x	x	x				VI, 3-b- 3-d
-12	Nursery diseases		x	x		x				x	x				VI, 1-a- 1-d
-13	Unknown diseases			x	x		x	x	x	x	x				VI, 4-e, 5-b, 5-c, 5-e
FS 2-d2	FOREST DISEASE SURVEY METHODS														
-1	Disease survey techniques								x						VI, 2-a, 5-a
FS 2-d3	DISEASES OF FOREST PRODUCTS														
-1	Decay of killed timber					x									VI, 6-a
-2	Decay of raw products												x		VI, 6-b
-3	Decay of wood in use								x		x		x	x	VI, 6-c
-4	Decay of modified wood												x		
-5	Natural durability												x		VI, 6-d
-6	Fungicidal properties of wood preservatives												x	x	VI, 6-e

[1] Research Locations

NOR - Northern
PNW - Pacific Northwest
PSW - Pacific Southwest
INT - Intermountain
RM - Rocky Mountain
LS - Lake States
CS - Central States
NE - Northeastern
SE - Southeastern
SO - Southern
ITF - Institute of Tropical Forestry
FPL - Forest Products Laboratory
WO - Washington - Beltsville

VII. FOREST PRODUCTS AND ENGINEERING RESEARCH

A. FOREST PRODUCTS UTILIZATION RESEARCH

Problem

The timber-using industry is an important part of our present economy. In 1959 the total value of shipments from timber-based primary manufacturing industries amounted to over $10 billion. About 5 percent of the Gross National Product originated in timber-based industries. One out of every 20 people employed in the United States worked in these industries. A raw material base for a greatly expanded industry is available in little-used species, in low-value timber, and in logging and milling residues. Research in forest products utilization is needed not only to give stability to the present industry but also to develop a technical basis for new industries.

The Federal Government has a strong interest and responsibility in forest products utilization research. The timber industry does a substantial amount of research. However, the industry is a complex of many small companies. Even the largest are small in comparison to those of other basic industries with whom they compete, i.e., aluminum, steel, plastics, and petroleum. One single large petroleum-using company employs more researchers than the entire timber-using industry. There are very few forest products companies who can finance a research program. Those that do are largely interested in developments which will give them a competitive advantage. Basic research by industry is largely neglected.

The problems are especially acute on the considerable acreage of timber in small ownerships. Here the continued "creaming off" of the better timber has resulted in residual stands of low value under present use standards. Research is needed to develop uses for this presently unmarketable timber.

The Federal Government itself owns and markets over a hundred million dollars worth of timber each year. The value of this timber can be greatly enhanced by the development of more profitable uses. Also proper forest management will be facilitated by developing markets for thinnings and other low-value timber.

The strength of the United States in times of emergency will also be improved by the development of industrial chemicals from wood. This will relieve petroleum which has been a critical raw material in times of war.

Program

The Department has a continuing long-term program involving both basic studies and applied research on problems relating to forest products utilization. Because its broad objective is to promote better utilization of the nation's timber resource, the required research and development draws upon the skills of many scientists in widely divergent fields. Involved are some 20 scientific disciplines in the areas of chemistry, engineering, mathematics, physics, and biology.

Basic studies are carried on in many subject areas to provide a solid background of fundamental information on the nature and properties of wood and its components and on the factors that affect those properties. Such research includes studies of strength, physical properties, chemical composition and reactions, anatomical structure, and resistance to decay, insects, fire and other destructive agencies.

Based on adequate background research findings, developmental work to improve the usefulness and the competitive position of wood and wood products proceeds in many ways. For example, improved preservative treatments may greatly lengthen useful life; improved glues and gluing techniques will improve the performance of glued products; and the development of precise design criteria for lumber, plywood, laminated wood, and fastenings for them will improve the performance of structures and, at the same time, reduce their cost.

Research that develops better standards of quality and value in trees and logs, better saws and more efficient sawing techniques, and other processes will be effective in extending the timber supply. At the same time, research that improves decay resistance reduces replacement requirements, and more efficient research-based design can reduce the amount of wood needed in structural units.

Wood requirements can be further reduced by research that results in expanding the use of cull trees, little-used species, small and crooked trees, and residues in the woods and in the mills, especially as related to chemical conversion and expanded development of glued and pulp products. The pulp industries, for example, depended for many years on a limited group of softwood species. As demand grew, technologic development brought about the use of additional softwoods and, more recently, a wide variety of hardwoods.

The key role that wood utilization research plays in the area of quality has been increasingly recognized in recent years by foresters, timber owners, lumbermen, plywood producers, and makers of wood fiber products. Rate of growth, density, fiber content, and other basic indicators of wood quality are all governed to a great extent by growth

conditions in the forests, and these conditions are in turn proving manageable to an extent that heavily influences the quality of the wood produced.

Research is under way to evaluate the intrinsic wood quality of standing timber; establish what effects such environmental factors as soil and rainfall, and such silvicultural treatments as pruning, have on quality; investigate by microscopic and other means how the physical structure of wood is related to its properties; and assist in the establishment of quality grades for trees and logs.

The processes and treatments by which wood is made serviceable, from the sawing of round logs to the utilization of sawdust and other processing residues, come within the scope of research on solid wood products. Included are the many kinds of operations involved in the processing and protection of wood in its solid form. The production of lumber, veneer, plywood, laminated wood, and particle board; machining operations; preservative and fire-retardant treatments; painting and finishing; glues and gluing techniques; and seasoning operations comprise the principal processing investigations under study.

Supplementing these are basic studies that encompass fundamental cutting actions of saws, knives, and other tools; chemistry of preservatives, fire retardants, adhesives, and finishes; pyrolysis and related effects of heat and combustion; and the growth and life cycles of decay and staining fungi, bacteria, and insects that attack wood.

Year by year, more and more wood is transformed into substances whose origin in trees is unrecognizable. Wood is our main source of fiber for myriad pulp and paper products, the demand for which continues to mount. By 1975, it is expected that 40 percent of all wood used will go into these products. As a result, greater pressure is put on our timber supplies and research is called on to broaden this raw material base.

An intensive program is carried out on pulping processes, on wood fiber properties related to pulp and paper production, and on the manufacture and properties of paper products. The object is to make hitherto unused species and qualities suitable and to produce more pulp from less wood.

Production of chemicals from wood is at a much younger state of development, necessitating primary emphasis of fundamental research and process development. Characterization of lignin, analytic studies of tall oil, and the potential of radioactive tracers in chemical research are parts of a program of chemical and biochemical studies designed to broaden the technical basis for future industrial development.

Research on wood products engineering deals with the establishment of the mechanical, physical, and related properties of the many species of wood commercially used, and the effects of use conditions on these properties. The same properties and conditions are investigated as they apply to plywood, laminated wood, chemically treated wood, fiberboard, particle board, paper and paperboard products, and composites of wood and other materials. Increasingly important is research on the use of wood in housing, farm structures, and other light-frame buildings.

A vital adjunct to the production of research information is its dissemination and application in practice. Although this can be done in part through the medium of publication, far better results are obtained by on-the-ground consultation and interpretation of research findings to specific problems. This is a prime responsibility of the Forest Utilization Research scientists at the Regional Experiment Stations. Furthermore, their frequent contacts and intimate knowledge of the regional wood-using industries permit them to determine significant problems in need of solution, and thus provide a basis for integrating them into a national research program.

Research is done mainly at the Forest Products Laboratory at Madison, Wisconsin, and at the Regional Forest Experiment Stations and the Institute of Tropical Forestry. Where suitable, however, cooperation is arranged with universities, other Federal or State Government agencies, private laboratories, professional societies, industry associations, or with industrial companies. Likewise, cooperative research may be done for industries or private individuals where its accomplishment ties in and will benefit the planned research program. During the past two years, cooperation has been with some 14 different colleges and universities involving about 35 different projects, with various Government agencies, both Federal and State, more than a dozen associations, and with many private companies.

The Federal scientific effort devoted to research in this area now totals about 147 professional man-years. Of this number, 15 are devoted to Wood Quality Research; 28 to Solid Wood Products; 10 to Wood Fiber Products; 21 to Wood Chemistry; 32 to Wood Engineering; and 42 to Regional Utilization Problems.

Research in this field is also performed by state laboratories such as those in Oregon, California, and Texas and by numerous schools. Substantial research is now going forward in industry-supported laboratories and those of individual companies. It is estimated that the total industrial research effort in this field involves the equivalent of about 2,000 scientific man-years; and that performed by public agencies outside the Federal Government about 100 man-years. Industry research is, of course, performed largely to obtain competitive advantage and is generally not freely available.

Within the past several years, a program of research in foreign countries has developed under Public Law 480. Many projects have been proposed in the field of forest products in 18 different countries. Currently five projects are underway involving about 10 professional man-years per year. One project in Peru involves collection of authentic herbarium samples and wood from Peruvian trees. Four Finnish projects are on factors affecting impregnability of wood, aerobic bacterial degradation of lignin, accessibility studies of cellulose fibers, and moisture-temperature-time relations as they affect wood strength properties.

Progress

1. Wood Quality

An overall problem analysis of timber quality research needs, initiated in Fiscal Year 1962, is scheduled to be completed during calendar year 1963. This analysis will provide an improved guide both to the Forest Service and to other research agencies in selecting for study specific segments of the wood quality problem.

a. Wood identification and fine wood structure. Investigations into the fine structure of wood have been greatly aided by electron microscopy, and a new optical science is being developed as a result. For example, optical evidence has been obtained for the first time of what was regarded as the smallest fundamental unit of wood, the crystallite or micell. Heretofore, this unit had been encountered only through chemical and X-ray diffraction techniques, by means of which measurements of its size in Angstrom units had been obtained.

Similarly, new evidence was obtained of the presence of lignin throughout the cell walls of wood and in the membrane-like toruses that close the minute openings in cell walls called bordered pits. A strong step ahead in this work was made possible by the finding (discussed under "Wood Chemistry," VII A, 4a) that hydrofluoric acid removes the cellulose from wood sections but leaves the wood structure intact. This technique has made it possible to attain for the first time visual evidence of the presence of substantial amounts of lignin in all three layers of the cell wall and the middle lamella. Heretofore, it had been thought that the tertiary, or S_3, layer was virtually pure cellulose. Significance of this finding to new pulping processes seeking to separate the layers of wood cells by differential shrinkage methods is considerable, as pointed out under "Wood Fiber Products," (VII A, 3a).

Also, visual evidence of the presence of lignin in the torus gives chemists firmer ground for planning new methods of chemically attacking these membranes to open up the bordered pits for passage of wood-treating liquids and other substances. This work has special application to such difficult-to-treat woods as Douglas-fir.

In the Southeast, a study to determine the relationship of gelatinous fibers to internal stresses in hickory showed that severely split hickory trees contained greater amounts of tension wood than the nonsplit hickory trees. Tension wood in split-prone trees was found to be distributed rather uniformly over the entire cross section of a stem.

b. Wood growth-quality and structure-property relationships. Studies showed that in Arizona ponderosa pine trees of pulpwood size (mean density 25.2 pounds per cubic foot at breast height) specific gravity declined upward in the stem to the 20-foot height and remained essentially constant above that level. A study of the anatomical features of loblolly pine showed that drought decreased summerwood formation near the base of the tree as compared with trees not having experienced severe moisture shortages.

Core density studies made several years ago showed trends of increasing specific gravity of the loblolly and shortleaf pines from northwestern to southeastern Mississippi. Somewhat similar trends have now been found in longleaf and slash pine from northern Georgia through Florida.

In 1960, core collection work was also launched in several western States. During 1961, industry began a 3-year financial contribution to that survey. It will involve collecting and analyzing some 26,000 cores. Being sampled are the main commercial softwoods, including Douglas-fir, western hemlock, western larch, Pacific silver, California red, noble, grand, and white firs.

During the past 2 years, over 13,000 increment cores from seven western States were processed for determinations of specific gravity and related data. Larger wood samples were also obtained from some 700 Douglas-fir, 500 white fir, and 450 trees of other western commercial species as a basis for relating whole-tree density to that obtained from increment cores. Analyses of the data are underway.

c. Log and tree grade development. During F. Y. 1961 and 1962, partial staffing was accomplished for all six sections of the National Log Grade Project. An improved system for grading ponderosa pine and sugar pine lumber logs in trees was developed and approved. An alternate product study on marginal southwest ponderosa pine logs showed economic benefit when logs were processed into chips in addition to lumber.

For the southern pines, the interim system of log grading developed several years ago was improved and adopted as Forest Service standard. Several additional yield studies were made to provide information and data essential to development of log and tree grades for several western softwoods. Factors were developed for converting grade yields under superseded rules to those rules now in effect. Butt-log tree grades that give good results in black oak work equally well in yellow poplar.

A number of studies, although incomplete, have shown significant progress in several other important areas. For example, a checklist has been prepared for evaluating the efficiency of commercial sawmills under consideration for use in special studies; and several photographic techniques

have been developed and are ready for field trials for recording external defects or characteristics of logs. It is hoped they will provide a better basis for evaluating interior defects.

2. Solid Wood Products

A new fundamental program for a nationwide study of the effects of climate on the service of wood products has been started. While exposure of new products to the weather and other actual service conditions to determine their serviceability has been practiced by the Forest Service for many years, little attention was paid in the past to such exposure variables as the surface temperatures of exposed products, the relative humidity of the adjacent air, and accumulation of water, snow, or ice on surfaces. Collectively these variables are known as microclimate, and may differ quite radically from conditions observed at the nearest Weather Bureau station. As the program is new in concept and execution, new instruments and procedures must be developed. Advice and cooperation of the University of Wisconsin Meteorology Department will be available.

a. Lumber manufacture. Experiments are underway on the production of pulpable sawdust from oak. This is a followup on work done with southern pine, in which it was demonstrated that production of pulpable sawdust particles resulted in excessive loss of potential lumber; the value of the lumber lost was greater than that of the sawdust chips produced. The theory has been put forward, however, that with hardwoods, which have much shorter fibers than softwoods, smaller sawdust particles might make acceptable pulp, hence less drastic sawing procedures could be used.

Preliminary design data and engineering drawings have been worked out in the design of an improved thin-rim, tapered-gage, inserted-tooth saw; the tooth kerf of which is only about two-thirds as wide as a conventional saw. A limited study on Eucalyptus robusta, a Hawaiian plantation species, showed that the National Hardwood Lumber Association lumber grade rules and Forest Service Standard Hardwood Log Grade specifications are applicable.

In the southeast, a procedure was developed for locating and recording log defects so that EDP techniques can be utilized for theoretically sawing a log in any desired way to determine the effect of defect orientation on lumber-grade yield. The feasibility of the technique was demonstrated on southern pine and yellow poplar logs.

A new simplified design for a solar-heated lumber dryer, the latest in a series of such designs experimentally developed during several years of research, proved especially effective. Two studies of red oak boards indicated that drying to 10 percent moisture content may be economically as well as technically feasible.

Heavy eastern hemlock 2- by 4-inch dimension lumber was uniformly kiln dried without development of shake or other defects. In cooperation with Purdue University, a prototype load cell was developed for use in dry kilns to measure the moisture content of lumber during drying.

b. Lumber conversion. A study has been initiated to determine clear-cutting yields from a selected sample of the five upper grades of 4/4 hard maple lumber. The size, type, and location of defects and blemishes are being recorded and these data will be arranged for use in an electronic computer to determine the maximum yields. This will provide a basis for selection of the most economical lumber grade for the production of any size and type of hardwood part.

A study of clear-cutting yields possible from No. 4 Common Eastern white pine, a major lumber item that industry finds difficult to merchandise, was made at the request of the U. S. Department of Commerce. It was aimed at determining the feasibility of conversion by use of finger and edge joining. Potential yields from this grade that can be estimated accurately by an experienced lumber grader are significantly related to board width but not to geographical origin of lumber.

c. Veneer production. Preliminary studies of the quality of veneer produced by rotary cutting with newly designed research equipment indicate that shelling, a serious defect, is related to growth rate, orientation of the annual rings, and pressure exerted by the lathe's nosebar.

Studies have been made to determine the effects of heating times and temperatures on veneer tightness, smoothness, color, and shrinkage. Other studies on conventional production equipment show that longtime heating of logs not only resulted in no improvement in veneer quality, but when high temperatures (200° F.) were used resulted in quality deterioration.

Slicewood, a product cut from logs by a knife instead of a saw, is nearly as high in bending strength as sawn lumber but is significantly weaker in tension perpendicular to the grain because of knife checks that develop during slicing. Although somewhat more likely to split when nailed, it can be fastened with air-driven staples without splitting, and is readily glued into straight or curved laminated products.

d. Glues. A unique new adhesive now being evaluated at the FPL is a thermosetting vinyl-emulsion system with apparent exterior serviceability. Basic studies have been initiated to determine the shear modulus of a cured adhesive by a new microtechnique for applying very small load increments and measuring very small strains in the adhesive layer. Work on various lignins as potential reactive extenders for phenol-resin glues for plywood indicated that some lignins are sufficiently reactive to be of interest, but the economics of such extensions are not attractive enough currently to justify further work.

e. Glued products. The outlook for the development of a large plywood industry from southern pine has not been felt promising in past years. The amount of compression wood in the available log supply was thought to be so great that the cost of cutting and discarding unsuitable veneer would prevent successful competition with plywood from other species. Also, the size of the logs seemed too small, and the probable speed of production seemed too low for successful competition with plywood from the western species. Recent studies show an improved outlook, partly because the amount of compression wood in the stands investigated was low enough to be acceptable, and partly because large, clear logs of competing species are no longer so readily available. As a result, several companies are now interested in commercial production of southern pine plywood, and there are good reasons to hope that a sound industry may develop. Additional research will be carried on as needed to aid this development.

A study on urea-formaldehyde glues showed that the most durable bonds were obtained with glues of the highest viscosity.

A new technique was developed for measuring strains in the glue joint of a very small specimen by use of a microscope. This research provides the first reliable determination of modulus of rigidity (shear modulus) of adhesives.

In an investigation of the geometry of finger joints, that is, length of fingers, slope of finger face, pitch of fingers, and thickness of the fingertips, a technique for preparing finger joints by band-sawing was developed to facilitate studies of a wide variety of joints.

Recent studies have affirmed earlier expectations that parchmentized paper performs well as an overlay material for lumber and for plywood. A mathematical method was developed that is expected to provide a basis for dealing with warping problems in composites.

In studies to evaluate the effects of typical and modified planer shavings on particle board properties, the shavings produced with a modified planer head proved more suitable than run-of-mill shavings. Moisture content, depth of cut, and knife marks per inch were also important. Results indicate that softwood lumber mills might well consider installation of new planing machinery in order to make particle boards that are greatly improved in stability and strength.

Experimental particle boards made of Douglas-fir flakes with various binders after 3 years of outdoor exposure showed that binders of phenolic resin, melamine-urea resin, or urea resin plus wax deteriorated only moderately. Boards with urea resin alone as the binder underwent almost complete deterioration.

f. Round wood products. Field research in Montana showed that spiral-grained larch and Douglas-fir poles with a left spiral twisted severely; poles with no spiral twisted less; and poles with a right spiral twisted least. The studies showed that trees in the juvenile stage mostly lay on wood with a left spiral, while older growth usually spirals to the right. A structural evaluation of spiral-grained poles indicated a reduction in strength in poles with left-hand spiral at the surface, and less effect in poles with right-hand spiral at the surface.

g. Wood finishes. After 6 years of exposure in Wisconsin and in the South, southern pine boards painted with an oil primer and two coats of a polyvinyl acetate emulsion paint showed little deterioration as compared with boards painted with four different oil paint systems. It is believed that the polymers in resin emulsions have better resistance to oxidative degradation than do oil binders.

An acrylic emulsion paint did not blister on eight different wood species in blister-box tests. In other blister-box tests, oil-base paints were found to blister when applied over various emulsion paints.

The promising results with overlaid plywood and lumber have prompted the launching of new basic studies to measure the microswelling in wood surfaces at wood-paint interfaces. The maximum swelling strains measured will serve as a guide in the search for polymers and finishes with suitable flexibility for use on exterior wood surfaces. Two precise techniques were developed for reproducing a wood profile and measuring the microswelling strains that develop in it during the process of swelling.

h. Wood protection. Studies have continued to find ways and means of giving wood, wood products, and wood structures greater safety from fire at a reasonable cost.

In dynamic thermogravimetric and differential analyses made of the pyrolysis reactions for wood treated with seven salts, effective fire-retardant salts generally lowered the threshold temperature and brought about most of the weight loss endothermically, while at least one retardant (borax) did not lower the threshold temperature, and brought about volatilization exothermically. The presence of fire-retardant salts significantly lowers the heat of combustion in the range from 30 to 60 percent volatilization, and the lowering seems to be directly related to the effectiveness of the flame retardant. Equipment and techniques were developed to study the effect of salt treatments for wood on the char-tar-water-gas products developed during fast pyrolysis.

A new technique for determining the corrosion characteristics of fire-retardant-treated wood, involving electrical resistance measurements,

was developed and evaluated. This method will probably be included as an alternate procedure in the military specification on fire-retardant-treated wood.

Comparative results by the 8-foot tunnel furnace and other flame-spread procedures on the flammability of wood products, both coated and chemically treated, indicate that at the lower range of the scale, the 8-foot tunnel furnace is a severe and critical procedure. Some of the better fire-retardant coatings reduced the flame-spread index value for Douglas-fir plywood by the 8-foot tunnel furnace method from 115 to 40, while heavy chemical retentions reduce the index value to 15. A relationship was established for many wood products between a basic property, "flame-propagation" temperature, and the flame-spread index as determined in the 8-foot tunnel furnace.

A preliminary study of the performance of adhesive-bonded and bolted and ring-connected joints between 2- by 4-inch wood truss members under combined fire and load exposure generally indicated a superior performance of the adhesive-bonded type joints, although improved design of the bolt- and ring-connected joints may be possible.

In the field of preservative treating methods, exploratory preseasoning treatments of green southern pine poles for fungus control showed excellent protection from brief immersion in high concentrations of ammonium bifluoride and boron compounds. These treatments show promising control after 4 months in semicommercial trials. A completed study on groundline treatment of five pole species showed surface paste applications to be superior to solutions poured around the poles or to spaced injection of chemicals in the groundline area. Two years after application, threshold quantities of the chemicals were limited largely to the outer 1/2 inch of the poles. A comparison of nine aromatic and aliphatic solvent carriers for pentachlorophenol showed none to be greatly superior to mineral spirits for producing clean and paintable pressure-treated lumber. A published summary of studies to improve the treatment of Rocky Mountain Douglas-fir showed high pressures and incising to have limited value, but indicated some promise for Boultonizing and steam conditioning of green material, for both oil and highly concentrated water-borne preservatives.

Materials that show promise as wood preservatives in recent laboratory tests included copper tallate, copper fluoborate, several lignite-tar products, several organic chemicals produced by new synthetic processes, and pentachlorophenol without oil carrier as obtained by the Cellon process. Detailed data on the distribution of four preservatives in pine and Douglas-fir lumber treated to known retentions showed promise for use in developing results-type specifications for treated lumber, based on the assay of boring samples. Treatment of cooling towers by double diffusion continued to look promising for fill slats, based on the condition of and low chemical losses from slats exposed as long as 9 years.

A new cooperative study with the Navy Bureau of Yards and Docks is aimed at improving the treatment and maintenance of marine piling. Under development are simple analytical methods for use in quality control-type specifications for procuring new piling or for inspecting piling in service. Analyses of piling that had given both good and poor service continued to show that the type as well as the amount of preservative initially injected can be very important in piling performance. Comparisons of the triethylene glycol-furfural (TEG-F) and specific-gravity-of-fraction methods for detecting petroleum in creosote indicated that TEG-F was somewhat more sensitive.

In the southeast, it was found that round slash pine, with bark-chipped and acid-treated turpentined faces, can be given a satisfactory preservative treated following the incising of the scarred faces.

3. Wood Fiber Products

a. Pulping processes. As in most research areas, new tools are opening new vistas in current pulping investigations. For example, further improvements in high-yield pulping are anticipated as a result of basic studies of the mechanism of wood fiber separation. (See also VII A, 1a) The goal is better treatments for removing the lignin-rich outer layers of cell walls from the carbohydrate-rich inner layers. Chemicals are being tried that cause the outer layers to swell differently than the inner layers, thus easing the problem of mechanical separation in a refiner. Fluorescence microscopy, which reveals in fine detail the surface structure of fibers, is being used to detect treatment effectiveness in causing separations within the fiber walls.

Three chemical pulping processes under investigation hold promise of greater pulp yield from softwoods. One, the polysulfide process, is under study to increase the efficiency of delignification in southern pine kraft pulping. It consists essentially of adding polysulfide to kraft liquor. It promises 15 percent more pulp than is obtained by straight kraft pulping from the same amount of wood. Such savings would mean substantially lower pulpwood costs and a $2- to $4-million saving in capital cost of a 300-ton, $25 million kraft mill. A drawback, excessive use of sulfur, is being attacked in continuing research. Injection or two-stage cooking appears to promise reduction of sulfur loss to levels now common in kraft pulping. The basic reaction mechanism of elemental sulfur and polysulfides is under intensive study.

Another, the bisulfite process, was investigated for production of newsprint and printing papers from softwoods. Pulps obtained were much stronger and cleaner than those produced by regular acid sulfite pulping. Yields of 55 to 60 percent also were appreciably higher, and the pulps were bleached to moderate brightness.

A third, the alkaline sulfite process, is being further evaluated for the production of bleachable semichemical pulps. Bleached spruce pulps were considerably higher in strength and yield than kraft pulps of the species. Possibilities of lowering lignin content and bleach requirements are being studied.

The high yields obtained from hardwoods with chemimechanical processes have led to trials with softwoods. In many paper and board grades, length of fiber is the prime requisite, color and physical properties being secondary. At current production rates for unbleached pulps, each 1 percent increase in yield attained by including more lignin is worth $16 million a year--an excellent value for lignin normally burned or otherwise disposed of! The substitution of semichemical for chemical softwood pulps in unbleached papers thus promises not only more complete utilization of wood but profitable utilization. FPL research is seeking to broaden the utility of semichemical softwood pulps even more by improving pulp color and strength.

Semichemical pulping was pioneered during the twenties by the FPL as a means of utilizing plentiful and low-quality hardwoods. The original neutral sulfite semichemical process has been notably successful toward this end--in 1960 about 2 million tons of pulp were produced by 50 United States mills using this process. Moreover, it has spawned related processes, both acid and alkaline, and a new more accurate generic term, "chemimechanical" processing. The processes are characterized by high yield, including substantial amounts of lignin. One of the newest is the FPL cold-soda process, which effectively doubles pulp yield as compared with the true chemical processes.

Cold-soda pulping continues to gain interest in the industry, and new equipment for fiberizing caustic-treated chips has been developed commercially. Pulps made from aspen and a mixture of eastern hardwoods in one new type of fiberizing machine were successfully used to replace lower yield chemical and semichemical pulps in fine papers.

b. Wood-fiber products. Research on paper production processes and treatments opened the way to significant improvements in strength, stiffness, and dimensional stability of papers ranging from container board to sorting machine punchcards and map and color printing papers.

As pulp passes through the paper machine, it is dried and pressed by rollers to form paper. The drying process causes the fibers to shrink together forming bonds between hydroxyl groups that are largely responsible for sheet strength. The amount of bonding depends mostly on the external surface area of the fibrous mass. Pulp processing, such as beating, increases the surface area, thus improving fiber bonding and sheet properties.

A water-permeability method of measuring surface area was found useful for measuring the improvement gained from beating the pulp. Surface area of an oak kraft pulp moderately beaten, for example, was increased from 12,500 to 58,000 square centimeters per gram of pulp. Bursting and folding strength of papers showed steady increases with increases in surface area brought about by beating and screening to remove fines (greatly undersize cells, vessel elements, and fiber fragments).

Restraining the shrinkage of paper sheets during drying resulted in three- to four-fold increases in stiffness of paper from long-fibered pulps. Reworked and unbeaten pulps were much less responsive. In other handsheet studies, the dimensional stabilization resulting from restraint during drying was studied. Dimensional changes can cause serious production and operating troubles with punchcards, maps, charts, and paper for color printing. The dimensional movement was dependent more on the amount of shrinkage during drying than upon pulp type, wood species, or degree of processing of the pulp.

Paper machine studies showed that, with expander rolls strategically placed in the press and dryer sections, the width of a sheet can be increased over that normally produced. A sheet made from processed bleached softwood sulfate pulp stretched on these rolls was 9 percent wider (9 inches more on a normal 100-inch sheet) and 50 percent more dimensionally stable when exposed to humidity changes. There was no significant loss in sheet strength such as often accompanies the use of chemicals to stabilize such papers.

Hardwood semichemical pulp was successfully substituted for up to 60 percent of the kraft softwood pulp generally used to make linerboard--the facings for corrugated sheets in container board. Semichemical pulp heretofore has been used only in corrugating medium. The experiments were followed up with pilot runs on a commercial machine and production of boxes that had adequate top-to-bottom compressive strength but somewhat lower impact resistance than boxes with all-softwood kraft liners. Research is continuing on ways to make the hardwood liners more impact resistant.

Among various chemicals tried for stiffening container board to improve stacking qualities, a 10 percent impregnation with phenolic resin offered most promise. The resulting board had compressive strength at 90 percent relative humidity equal to that of an untreated board at 50 percent. Wax emulsions and some water repellants were entirely unsatisfactory. A surface application appeared to be better than complete penetration of the chemicals. Surface application was done best at the size press on the paper machine, where the sheet is practically dry.

Investigations on the effect of cell wall thickness of honeycomb structures on the properties of the resin-treated core showed that the compressive strength and modulus of elasticity, important to certain structural applications, decreased with increases in the thickness of the paper in the cell wall. This was due, in part, to the manner in which the resin deposited on the paper.

4. Wood Chemistry

a. Lignin chemistry. The spent liquor from sulfite pulping and its counterpart, the so-called "black liquor" from sulfate (kraft) pulping, are both processed to some extent to recover useful compounds. Uses include application as a dispersing agent, replacements for carbon black in rubber, boiler water conditioners, and oil-well drilling muds. Sulfite liquor lignin is additionally used as a roadbed stabilizer, for production of yeast, vanillin food flavoring, and alcohol. The tonnages of lignin removed from wood by pulp mills, however, are so vast that existing uses consume only a small fraction.

Research on the possibility of obtaining other simple, potentially useful compounds from black liquor is underway. Anticipated products include alkyl-substituted phenols, methoxy phenols, and a series of catechols. New microkinetic techniques will be used to gain estimates of quantities potentially available.

Long-term basic research aimed at more complete characterization of the lignin molecule, however, offers the best hope for ultimate large-scale utilization of this chemically elusive substance. Being sought is a more precise description of lignin as it occurs in the tree. Recent studies involving synthesis of complex model compounds yielded strong evidence that biphenyl-linked building units account for perhaps 30 percent of the lignin molecule. Work is going forward on means of separating products that may contain biphenyl linkages, which are especially resistant to cleavage into simpler compounds.

Lignin has been isolated from maple, loblolly pine, and spruce woods by means of hydrofluoric acid. Its physical structure has been examined in the electron microscope and its reactions studied by micro techniques that were developed for this purpose. This lignin has chemical properties similar to other acid lignins. The electron microscope studies provided the new information that lignin is fairly uniformly distributed throughout secondary wood cell walls in both hardwoods and softwoods in lesser quantities than in the middle lamella, and is present in the tertiary cell walls of these woods in quantities nearly as great as in the middle lamella. (See also VII A, 1a)

A spectrophotometric method for determining the lignin content of wood in small samples was developed. A sample of wood is dissolved by treating it with acetyl bromide in acetic acid, and lignin content is computed from the amount of light absorbed by the solution at a wavelength of 280 millimicrons. Measurements are reproducible, rapid, and inexpensive.

b. Cellulose chemistry. A new process was developed for cellulose nitration, and a patent was obtained. Nitration is accomplished by treating cellulose with anhydrous mixtures of nitrogen tetroxide and hydrofluoric acid. The process may lend itself to continuous production of cellulose nitrate in sheet form, and has some advantages in the ease with which it can be stabilized.

The low-temperature behavior of solid rocket fuels containing nitrocellulose was studied for the Army Ordnance Corps. Proper use of the information obtained offers a means for modifying the low-temperature plasticity of cellulose nitrate propellants over a considerably range.

c. Biochemistry. Research on the conversion of wood sugars to useful chemicals by fermentation with osmophilic yeasts is being pursued with two chemicals of considerable potential commercial use as the principal targets. On one, erythritol, laboratory work was nearly completed and has attracted some commercial interest. This polyol is a rare chemical, sells at a high price, and must be imported. At lower prices, however, it can be expected to find promising uses in plastic resin and coating formulations.

Another fermentation study in its early stages aims at production of itaconic acid from hexose and pentose sugars. This dibasic acid is of commercial interest for certain types of plastics because it can react both through its carboxyl groups and its double bonds.

d. Physical chemistry. Polyethylene glycol, a waxlike chemical that dissolves in water, was found several years ago to be a good stabilizing agent when introduced into the fine cell wall structure of green wood. The unprecedented reliability of wood gunstocks chemically stabilized and seasoned by this fiber-bulking process was dramatically demonstrated recently by the U. S. Marine Corps Rifle Marksmanship Team. Through drastic changes in climate, the rifles fitted with treated gunstocks remained highly accurate in target competition while weapons fitted with untreated stocks had to be "zeroed in" and barrel-to-stock fittings adjusted repeatedly because accuracy was lessened by slight dimensional changes in the stocks with changing relative humidity. Since the polyethylene glycol treatment is expensive, one current goal of dimensional stabilization research is a simple process that will do an acceptable job with little chemical at low cost.

A nuclear magnetic resonance technique was found to be useful for measuring the relationship between moisture content and the tightness with which moisture is bound to wood. The same technique was used experimentally to relate mobile hydrogen content of wood and moisture content. Since the relationship is not limited to moisture content levels below the fiber saturation point, the method appears to have possibilities for nondestructive measurement of all moisture levels.

In a study of the surface properties of wood, a specific affinity was found to exist between polyvinyl acetate and wood surfaces. Adsorption of this polymer was found to be greater in swollen wood, and the lumen walls of wood were shown to play an important role in the adsorption. Exploration is continuing on the factors that affect the bonding of such polymers to wood.

e. Process development. Research on a dehydration process for making furfural from the xylose fraction of hemicellulose has shown that the process is economically as well as technically feasible if the hemicellulose fraction need bear only its proportionate share of the wood cost. Furfural is used in resin manufacture, as an extracting solvent to purify lubricating oils and gasoline, and for other purposes. It is now made from corncobs and bagasse. Technical production problems were explored in a pilot-scale preheater-reactor unit. It was found that solutions containing hexose and pentose sugars can be fermented to alcohol, processed to convert the pentoses to furfural, and the alcohol and furfural can be recovered in the same still with marked economy in use of equipment and steam. Such a process can be attractive under the proper circumstances.

Using a highly efficient experimental technique, valuable processing data were obtained on the delignification of aspen wood with sodium xylenesulfonate, a hydrotropic salt. The data are of general interest, as it is thought this system will have application as a solvent for removal of lignin and hemicellulose prior to processing wood to chemical products.

An extensive program of research on charcoal production, carried out by FPL in cooperation with the Lake States and Southeastern Forest Experiment Stations, was completed with publication of a joint report. Data are given on marketing and use as well as on production. Analytical procedures for charcoal evaluation have been accepted as a tentative ASTM standard.

5. Wood Products Engineering

a. Properties of wood. The forerunner of a major re-examination of important western species got underway during 1961 with a study of the basic strength properties of white fir (Abies concolor). This re-examination will be done as part of an overall survey of the quality of standing timber in various parts of the United States, as discussed elsewhere in this report under the heading, "Wood Quality," (VII A, 1b). Tests on all green material and about half the air-dry material have been completed. A program is being prepared for machine computation of the results of this and future similar studies. Properties of green material of these four shipments, including specific gravity, are essentially the same as those of other material of the species evaluated previously. The greatest difference was observed in modulus of elasticity in static bending, for which the new data may raise the overall species average by about 5 percent.

A moderately dense Hawaiian hardwood, Eucalyptus saligna, has been partially evaluated and is considered to have potential as a structural species as well as for general use in that State. The experimental work and most of the analysis was also completed in an investigation of silk-oak (Grevillea robusta) form Hawaii. Hardness of air-dry material is much lower than that of yellow birch and is comparable to that of air-dry material of paper birch. Shrinkage

is less than that of the birches, and is generally similar to that of black cherry or red lauan.

Basic research on the physical properties of wood was continued, with a major object the development of nondestructive tests that reliably measure strength. One type of nondestructuve test that shows promise of commercial application consists of measuring the rate at which vibrations along the length of the piece are damped off. Resonant frequency has been shown to be closely related to modulus of elasticity, and internal friction has about the same relationship to strength as does specific gravity. Preliminary evaluation of the use of radioactive isotopes to measure wood density and moisture content and to locate voids in wood also indicates promise for radiation techniques as a means of nondestructuve evaluation of wood properties.

Evidence that fire retardants reduce flexural strength and stiffness of wood was obtained in exploratory experiments on southern pine and Douglas-fir treated with two kinds of commercial retardants. This work prompted a more fundamental study that is designed to evaluate individually the effects of various chemicals and treatments on the strength of different species. Industry groups are supporting this work.

An intensive study of the fatigue properties of wood in flexure and shear was completed. Analysis of the data on quarter-scale bridge stringers of southern yellow pine and Douglas-fir indicates that present methods of deriving working stresses for timber generally provide an adequate margin against bending fatigue failure in service. Only in shear is further consideration of allowable stress indicated, and this is apparently most critical in treated material. Further fatigue studies have demonstrated that effects from knots and drilled holes may be cumulative with slope of grain in reducing fatigue strength.

Research conducted with new equipment indicates that perpendicular-to-grain mechanical properties of ponderosa pine are related to temperature, moisture content, and growth ring orientation in a manner generally similar to that previously reported for red oak. A program is being developed for the IBM 1620 for calculation of internal stresses in wood during drying.

Research on dynamic strength and elastic properties of wood indicated that dynamic loading had little effect on stiffness but resulted in a 25 to 50 percent increase in modulus of rupture.

b. Properties of wood-base and related materials. A major investigation of the strength of hardboard, other fiberboards, and particle board was launched during 1961. These materials have come into extensive use for structural purposes, and for these uses their strength and related properties needed to be more precisely defined by research. The work begun last year is expected to continue for 4 years. Since its inception, the work has won cooperative support of the American Hardboard Association.

The program contemplates evaluation of plastic and elastic behavior under various kinds of loadings, effects of duration of stress, fatigue, and rate of loading, and time-temperature-moisture content relationships for hardboard and building fiberboard. Procedures for adequately measuring shear strength in the plane of the panel, a property important where a panel is used as a stressed skin or structural sandwich facing, are under development.

c. Analytical mechanics. Although the strength properties and engineering criteria of plywood have been deeply studied at the FPL over a period dating back to World War I, the broad use of this material today frequently brings up new questions requiring Laboratory investigation.

For example, a major producer of missiles requested information about plywood as a structural cylindrical shell in a missile. From the ensuring study, a mathematical analysis was developed for the buckling of such shells under external radial pressure and experimental data closely verified the mathematical theory.

The dramatically different structural designs for which plywood is used--vaulted roofs, multicurved shapes, space planes, and the like--also bring up design problems. Deflection studies of flat plywood under load, for example, disclosed that failure can occur in compression at the panel edges rather than in flexure. A theory for predicting such behavior in mathematical terms is being developed for designers.

An investigation of the load-carrying capacity of multiple-bolt joints in heavy Douglas-fir timbers showed that each bolt carried 80 to 90 percent, on the average, of the maximum load supported by a single-bolt joint. In green lumber, multiple-bolt joints carried only about two-thirds of the load comparable joints supported in dry material.

d. Structural development and use. Structural research on housing recently has been focused on the performance of materials and structural elements under normal service conditions. To obtain more accurate data on such conditions, a survey was completed during 1961 on temperature buildups within houses. The data were taken in houses at Tucson, Ariz., Athens, Ga., Portland, Oreg., Lufkin, Tex., and Madison, Wis. In addition to several Forest Service units, the Texas Forest Service and the University of Arizona were involved. Data showed maximum roof temperatures up to 160° F. Surface texture and color of roofing were found to have pronounced effects on temperature, and the value of attic ventilation in reducing temperature was strongly confirmed.

More efficient designs for timber highway bridges are being developed cooperatively with the Division of Engineering of the Forest Service. A mathematical theory developed for calculating stiffness of a three-stringer bridge checked out with experiments in the laboratory, and a general analysis for the stiffness of a multistringer bridge was completed.

To investigate the factors involved, and to obtain limited data regarding effects on strength properties when prestressed reinforcing strands are incorporated in the tension portion of wood bending members, six pairs of laminated beams were evaluated, one of each pair being unstressed and the other prestressed. Although the results are limited, they indicate that prestressing will increase the load-carrying capacity of wood members subjected to bending. Further research is needed to explore the potentials of this concept for laminated wood and solid wood members.

A lengthy and complex investigation of the strength of wood poles was completed with the issuance of a report on results by the cooperator, ASTM. This report has been sent to the American Standards Association, with which FPL is cooperating on revision of "American Standard Specifications and Dimensions for Wood Poles," primarily to develop a schedule of fiber stresses and establish defect limitations. The object of this program is to provide a more comprehensive basis for engineering evaluation of poles of major species for use by utilities.

For the Navy Bureau of Ships, flexural strength of laminated Douglas-fir beams that had been immersed in salt water was investigated. Neither strength nor stiffness was found to be significantly affected by up to 9 million cycles of loading to 45 percent of estimated maximum strength.

e. Packaging. Because of its long-standing role in packaging research, the FPL is widely consulted by other Government agencies concerned with packaging and shipping specifications. Currently an extensive job of standardizing packaging test procedures is being done for the Navy Bureau of Naval Weapons. More than 1,400 test procedures have been extracted for review from some 335 Government packaging specifications; each is referred to the most qualified member of the FPL staff for review and improvement. After military coordination and acceptance, they are included in Federal Standard No. 101.

A manual recently completed by the FPL to aid Air Force packaging and procurement personnel in estimating costs of packaging is being given trial use by the Navy and the Army Ordnance Corps. Estimates of impressive savings through its use have been received. In one 10-month period, Air Force savings on procurement contracts reportedly amounted to $2,243,000. A West Coast packaging consultant said that $247,000 was refunded to the Air Force on one contract on which he had used the cost manual. Assistance was given the Joint Military Packaging School in preparing a training course on use of the manual.

Research made possible a noteworthy advance in the design of bin pallets, now widely used for harvesting and shipping apples, cirtus fruits, and some types of vegetables. An evaluation of 11 bin-pallet designs by means of simulated weathering and rough-handling tests demonstrated desirable

construction features, and results have been widely published among users of agricultural bin pallets.

A collapsible wood bin pallet was designed in cooperation with the Agricultural Marketing Service of the U. S. Department of Agriculture and put into service tests by a grocery chain for experimental transport of potatoes from growers to terminal markets.

At the Carbondale, Ill., Project Center of the Central States Forest Experiment Station, 90 pallets made of green and dry lumber are being periodically inspected while in service. After 2 years, edge deck board of green lumber are showing considerably more failure than those of dry lumber, and there is much more objectionable protrusion of nail heads.

Since 1940, a study has been in progress on the stacking loads that can be sustained by corrugated fiberboard boxes in longtime warehouse storage One phase currently under investigation is the effect of different types of box contents. Three kinds of contents are under study; one prevents box sides from bowing in; a granular type "flows" as the box is deformed; and one of water in a flexible barrier also flows, but with less restraint than the granular type. Effects of each type will be analyzed to determine how it affects the resistance of the box to stacking loads encountered in storage.

Another study deals with the most efficient distribution of wood fiber in corrugated board. Currugated board was made in the laboratory from liners and corrugating mediums of various weights. Results indicate that weight added to the liners produces more strength than when an equivalent amount of weight is added to the corrugated section.

Several adhesive materials have been found promising enough in evaluation of some 30 combinations of plastics, adhesives, and mastics to warrant investigation of their performance in vegetable and fruit lug boxes. One of the best is a rubber isolator glued between box parts. A seam compound and a castor polyol type of adhesive were found to be nearly as good in evaluation of simulated box corners under impact loading that imposed tension, shear, and spreading forces on the joint.

The dynamic loading capabilities of nails, lag screws, and bolts were examined with pendulum-impact type apparatus to establish requirements for fastening blocking and bracing in place in crates to prevent shifting of contents during transit. Blocking and bracing are also used to restrain movement of containers and heavy equipment shipped on railroad cars and other cargo carriers. Special electronic equipment was devised to observe, measure, and record reactions to dynamic forces imposed on the fasteners.

6. Regional Utilization Problems

A national research program necessarily is made up of those regional and interregional problems which have national significance. Since 1944, the Forest Service Forest Products Utilization Research program has been guided and serviced by small, grassroots staffs of well-qualified forest products technologists located at the Forest Experiments Stations. Now established as Divisions of Forest Utilization Research, these staffs have contributed to the Forest Products Utilization Research program in many ways, primarily in:

a. Investigating the overall regional situations to isolate problems and to evaluate the possibilities of problem solution by research.

b. Planning and initiating research studies aimed at solving regional problems.

c. Cooperating with regional research agencies in solving problems.

d. Assisting regional industrial and public-service agencies in carrying out activities and programs on regional problems.

e. Providing consultation and advice to regional extension and action agencies.

f. Maintaining close liaison between regional industrial and institutional research groups and the Forest Products Laboratory.

The sum total of these contributions has been to make the Laboratory more responsive to regional needs and to make more effective application of research results and improved local effectiveness in solving regional problems. The details of actions and accomplishments by the Station FUR Divisions during the past 2 years can be only broadbrushed here. A few are mentioned primarily as illustrations.

a. Regional problem analyses. At all stations, regional analyses have gone forward, not only in the selection and segregation of major regional problems, but also in the detailed analyses of the specific problems selected. In the Pacific Northwest, one of the senior forest products technologists has been assigned full time to an analysis of a needed program in the field of timber quality. Supplementary specific analyses have been made in subjects such as log and tree grades, structural grading of lumber and plywood, and timber harvesting. The results of these analyses are being used to draft Line Project Descriptions for expanded FPUR programs.

b. Solving regional problems. When confronted with all sizes and types of regional problems, solution may range from the quick and easy to the infinite in both time and effort. Local studies by the Forest Service FUR Divisions mostly have been reported previously, since they normally supplement the research program of the FPL. In some cases, however, demonstration-economic type studies have been carried on locally in order to aid in the solution of problems that are not a part of the national research program.

(1) In the Central States, progress has been made in the increased utilization of low-grade hardwood lumber by demonstrating its economy and potential in using oak for minor farm structures, oak and hickory for picnic tables to meet expanding Forest Service recreation needs, hickory for stadium seats, and the hard hardwoods for pole-type building construction. Studies are going forward on the performance of wood "brick" for specialized applications.

(2) In the Southeast, cooperative studies with FPL and industry have been completed on the outdoor storage of pine pulpwood chips, indicating that long-time storage is feasible but results in a loss in pulp tear strength of about 5 percent per month of storage time.

(3) In our new State of Hawaii, the Southwestern Station has helped to establish local studies of the treatability of native species, of air drying, and of stabilization treatments for craft woods. That Station also arranged for studies of six Hawaiian woods at the FPL, financed by the State of Hawaii.

c. Regional research cooperation. A major function of FUR field effort is to assist and collaborate with established State or regional research agencies to seek a coordinated approach to the solution of regional utilization problems.

In general, this function has been most effective in our relationships with generic groups such as state forest products laboratories and schools of forestry, state agencies planning research facilities and programs, and regional or state industrial groups concerned with research. Illustrating the application of this function are the following:

(1) Planned programs have been completed with the objective of encouraging the increased utilization of the problem species--beech (in the Northeast) and hickory (in the Southeast). Under the leadership of the Stations concerned, regional research assignments were made and results published in areas concerned with the objective.

(2) Guidance and coordination has been given to the programs of such regional groups as the Western Dry Kiln Clubs and the Southeastern Dry Kiln Clubs in studies to determine the equilibrium moisture content levels of wood in use.

(3) The Western Wood Preservers' Association (Research Committee) was assisted in its work plan preparation for studies of utility poles and crossarms.

d. Regional activities and programs. Participation in regional technical and industrial association activities is an important function of our FUR personnel. In all regions this participation follows a pattern of leadership and technical contributions to groups such as the Forest Products Research Society, Society of American Foresters, and State and regional committees and associations.

Another facet of regional efforts is covered by consulting advice, sometimes assisted by the FPL, to encourage the establishment of industries or to take other action needed to aid in the solution of regional problems. During the past 2 years, this type of contribution has helped to establish:

(1) A $32 million pulp and paper mill at Snowflake, Ariz., producing newsprint, kraft paper, and linerboard. This mill will employ 325 workers and will consume 150,000 cords of pulpwood each year, in addition to large volumes of sawmill residue chips.

(2) In Trinidad, Colo., a new integrated lumber and dimension stock operation is getting underway. This plant will relieve some of the economic distress resulting from a decline in mining activities. Financing was aided by the Small Business Administration and the Area Redevelopment Administration.

(3) A Wood-Use Demonstration Center is being established at Quicksand, Ky. Sponsored by the State and partly financed by the ARA, the purpose of this Center is to stimulate the economy of eastern Kentucky. Low-quality hardwood timber will be used as the raw material for new and improved products and processes, which will be demonstrated at the Center.

(4) In Maine, collaboration was obtained from the Northeastern Lumber Manufacturers Association in a study of yields from low-grade white pine, which led to an ARA loan to establish an end-gluing operation at Biddeford, Maine.

e. Assisting extension and action agencies. The application of research results necessarily must be brought about in many different ways. Our Station FUR work program emphasizes maximum assistance to the established public extension and action agencies to do this.

Assistance to extension agencies has involved primarily technical advice and guidance and the training of extension workers. Our points of contact are the State Extension Services, the Forest Service Regional Divisions of State and Private Forestry, and the Cooperative Forest Management staffs of the State Foresters. With the assistance of the FPL, backstopping and training has continued actively for these groups.

Help to action agencies has been concentrated on the Small Business Administration and, more especially, on the Rural Area Development activities of the ARA. All Stations have assisted in RAD basic planning and on the details of development programs, pilot economic studies, and investigations and recommendations on specific proposals. Activities have varied all the way from a proposed sawmill enterprise in Fairbanks, Alaska, to lumber marketing problems in Georgia.

Typical of one phase of assistance to action agencies is the conference on "Forest Industry Opportunities in Rural Development" held in Harrisburg, Pa., in November 1960. Organized largely by the FUR Division of the Northeastern Station, this conference served to stimulate the RAD portion of the ARA program in the Northeast.

The Stations also made investigations and furnished case histories and costs which formed the basis for a publication by the Forest Service entitled, "Forest Industry Opportunities in Rural Development."

f. Regional-FPL liaison. The Station FUR Divisions function basically as regional representatives of the Forest Products Laboratory. The performance of this function pays large dividends--to the FPL in improved research program quality, balance, and effectiveness; and to the Regions in problem solution, technical backstopping, and economic advances. During F. Y. 1961 and 1962, liaison activities at the Stations have continued along the following lines:

(1) Assisted in arranging the acquisition (or expansion), fencing, and maintenance of National Exposure Sites at Olympia, Wash., Fresno, Calif., and Gulfport, Miss.

(2) Helped substantially in the survey of western timber specific gravity (see the "Wood Quality" section of this report) in initial contacts, sample area location, industry contacts, and field assistance.

(3) Selected research material and arranged for its protection and shipment for FPL studies on pulping, natural durability, extractives, specific gravity determinations, particle board production, lumber production and mechanical properties.

(4) Facilitated the arrangement and execution of eight contracts between universities and the FPL under the Cooperative Aid Research Program in which research is supported by FPL funds.

(5) Enlisted FPL cooperation on interregional problems in which research can contribute to a solution. The outstanding recent example is a joint study of the low-grade ponderosa pine problem in the Southwest and Rocky Mountain areas. The Laboratory and the Rocky Mountain Station are working on products and processes suited to the use of this material.

(6) Informed the FPL of significant regional research and technical developments which bear on its program. Among the more important of these were: (a) In nondestructive timber testing, progress in application of a stiffness-testing device at Potlatch Forests, Inc.; and parallel progress at Washington State University on the correlation of strength properties and resonant frequency and vibrational decay. (b) A defect-scanning device, developed cooperatively by the Western Pine Association and Batelle Memorial Institute, for the automatic removal of lumber defects by trim saws. (c) Development and commercial application of VHF drying to green furniture squares and dimension stock. (d) The ultrasonic cutting of organic material, developed by the Fullam Laboratories, and the possibility of this application to cutting wood.

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B. FOREST ENGINEERING RESEARCH

Problem

Multiple-use requirements dictate that new, revolutionary and complex engineering systems be developed to permit protection and maximum utilization of our forest resources under intensive management practices. Research in this field has been confined to projects with relatively limited objectives in contrast to the need for coordinated systems required by multiple-use considerations. National forest lands of many uses pose a challenging problem in utilization and protection due to their relative inaccessability and land management objectives.

Results of a recent study indicate that in Oregon and Washington alone there are at least 28 billion board feet of timber, characterized by low volumes per acre, steep growing terrain and costly road access, which will require special harvesting and removal techniques. (Eight western senators have urged early Forest Service evaluation of the helicopter as one possible solution to this problem.)

An additional 55,000 miles of access roads are estimated to be required for harvesting the timber cut planned on National Forests alone in the next ten years. Vastly improved transport and harvesting methods are needed to protect soil and water resources, to harmonize timber harvesting with other multiple-use requirements such as recreation, and to avoid loss of productive growing areas to road rights of way.

In Alaska there are an estimated 61 billion board feet of timber which cannot be successfully logged with the conventional systems that are costly to the operators and damaging to soil, water, and aesthetic values.

Logging systems and equipment for economical timber harvesting and cultural operations on small woodland ownerships are nearly nonexistent. Specialized equipment is urgently needed.

In eastern hardwoods some 74 percent of the total volume is considered low grade and culls, requiring vastly cheaper harvesting methods so they can be removed economically and the sites replanted to improved species.

Sharply reduced nursery and planting costs are needed to accelerate the job of replanting 52 million acres of commercial forest land--about 11 percent of all commercial forest land.

Program

The possibilities of engineering research in multiple-use forestry operations are being expanded almost daily by the rapid development of new materials and methods of construction, new chemicals, new forms of transport, new forms of energy and new devices for automatic control. We are experiencing a tremendous explosion in technology and the need now in forestry is to perfect the engineering systems to take advantage of these advances.

Seven major problem areas involved in multiple-use forestry have been selected and plans made to establish engineering laboratories in the geographical area in which each problem is dominant. Most problems are not confined to a single geographic area, consequently, each Laboratory will have national, or at least interregional, responsibility for its assigned mission. The research will be primarily applied.

Research in each problem area will begin with an engineering systems analysis. The first step in the analysis will be the preparation of a prescription for the job to be done. It will define the performance goals and the criteria for attainment of the engineering system or process required. The next step will be synthesis, or model building, wherein real systems will be simulated as a means of evaluating alternative forms of operations.

The translation of multiple-use land management requirements and operations into engineering terms and "systems of operations" is a pioneering attempt in both engineering and forestry which requires new approaches and concepts, and much imagination and inventiveness.

The total process can then be divided into subprocesses for further study and design. The final step will be systems development, involving the creation of new types of equipment, improved methods, and new concepts of process organization.

Once the specifications are drawn, a review and appraisal will be made of any and all items of existing equipment believed capable of meeting requirements. If existing equipment cannot meet the specifications, it will be necessary to obtain modifications or to develop prototype new equipment. To the extent possible, private industry will be encouraged to do this work, either independently or by contract. If industry help cannot be obtained, the work may have to be done by the Forest Service.

The prototype or modified equipment will then be tested against the specifications. If necessary, a production model will be obtained and tested against the job to be done.

Close liaison will be maintained with other agencies, both domestic and foreign, engaged in forestry and equipment development and with equipment manufacturing industries, as well as with defense laboratories, to determine whether presently developed equipment, processes, or techniques can be advantageously applied in forestry operations. The program will be directed particularly to original applications designed to revolutionize forest production, protection, and utilization while considering other multiple-use requirements.

Laboratories have been established by assignment of project leaders at Auburn, Alabama (Auburn University); at Houghton, Michigan (Michigan College of Mining and Technology); and at Bozeman, Montana (Montana State College). Each is closely associated with the engineering college or school where mutually profitable cooperative research programs are planned. Fiscal Year 1963 plans call for establishment of a laboratory at Seattle, Washington (University of Washington).

The objective of the work at each laboratory will be to improve the efficiency and economy of forestry systems in its assigned problem area. (Included in the systems are methods of harvesting and transportation, re-establishment of forests, timber stand and watershed protection and improvement, and providing means of access for all multiple-use purposes). The assigned problem areas are:

Auburn, Alabama--Intensively managed timber stands and component forestry operations in seed production and nursery operations.

Houghton, Michigan--Deteriorated northern hardwood stands located, generally, in rolling terrain.

Bozeman, Montana--Relatively small-sized timber on steep slopes and erosible soils.

Seattle, Washington--Virgin timber stands and utilization of heavy residues characterized by West Coast and Alaska forests.

The Federal scientific effort devoted to research in this area totals seven professional man years.

Progress

The engineering research program of the Forest Service represents a new approach. Work to date has therefore been largely concentrated on the development of engineering systems analyses. Project work has been on a cooperative basis as follows:

1. Helicopter Logging.

Prior to initiation of a formal engineering research program in the Pacific Northwest (planned for Fiscal Year 1963) studies were begun in cooperation with Oregon State University on "Some Factors Affecting the Feasibility of Helicopter Logging in the Pacific Northwest and Alaska." The study, begun June 6, 1961, and concluded March 31, 1962, was headed by John E. O'Leary, Associate Professor of Forest Engineering, School of Forestry, Oregon State University, Corvallis, Oregon.

The results show that, because of the very high operating and overhead costs, helicopter use for commercial logging at present must be confined to situations where the following factors can be maximized:

(a) Short haul or turn, probably less than 2 miles. The helicopter is essentially a flying crane not a transport device.

(b) Quick hook-on to load. One piece loads will greatly improve efficiency of operation.

(c) Maximum volume in board feet per turn. Since densities may vary from five to fourteen pounds per board foot, areas where low density woods prevail should be sought.

(d) Quick release of load. A water dump would require the minimum time.

(e) Good weather. Dense fog, sleet, and winds in excess of 35 miles per hour will ground a helicopter.

(f) Low temperatures and elevation.

(g) Gentle topography. Although a helicopter can log any slope, safety of ground personnel and speed of operations will be favored by gentle slopes.

(h) Clear cut operations to minimize pick up time and increase safety.

(i) Minimum variation in tree weights. Matching of loads to helicopter capacity improves "load factor" and efficiency of operation.

(j) Availability of spare parts and other "ground support." Maintenance is a huge cost in helicopter operations and every effort must be made to facilitate it.

Examination of the factors listed above indicates that Southeast Alaska is the most likely area for a full scale successful commercial operation at present day helicopter logging costs.

Cooperative studies at Oregon State University are continuing with plans for logging trials using smaller type helicopters to develop hook-on and release techniques and time factors. Investigations are planned into systems and procedures for estimating log and tree weights so that "full-load" packages can be prepared to match the helicopters lifting capability.

2. Pipeline Transportation.

Cooperative studies were begun in 1961 at Montana State College to investigate the feasibility of "Continuous Flow Transport of Low Value Forest Products by Hydraulic Pipeline." The study has been headed by Dr. William A. Hunt, Assistant Professor, Department of Civil Engineering and Mechanics, Montana State College, Bozeman, Montana, under the direction of Mr. H. Minor Huckeby, project leader for engineering research, U. S. Forest Service.

On the basis of design factors and criteria developed the study showed that, hydraulically, the transport of large volumes of wood chips in water pipelines is feasible. Estimates of "out-of-pocket" expenses for delivering 85 tons per hour of chips a distance of 50 miles were $. 015 per ton mile using a 12-inch pipeline, and $. 036 per ton mile for truck haul. These figures indicate that the pipeline system warrants a complete engineering economic analysis.

Studies are continuing at Montana State College to investigate the engineering economics of harvesting systems utilizing pipelines for chip transport. Processes for continuous supply of water and chips into, and out of, the pipeline require considerable study and evaluation. Hydraulic and operational problems including flow control, feeding methods, and pulp performance requirements are to be studied. Three pipeline systems are to be investigated--a basic material transport mainline, an inter-plant system, and an intra-plant system.

WORK AND LINE PROJECTS, Forest Products and Engineering Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]													Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 3-a1	PRESERVATIVE METHODS AND SERVICE STUDIES														
-1	Preservative treating methods				x		x			x		x	x		VII, A-2-h
-2	Field and service studies				x	x	x			x			x		VII, A-2-h
FS 3-a2	CHEMISTRY OF WOOD PRESERVATIVES														
-1	Chemistry of preservatives												x		VII, A-2-h
-2	Treatment of farm timbers									x			x		VII, A-2-h
FS 3-b1	GLUES, GLUING, AND VENEER MANUFACTURE														
-1	Veneer manufacture									x			x		VII, A-2-c
-2	Properties and uses of glues									x			x		VII, A-2-d
-3	Gluing properties of wood												x		VII, A-2-e
-4	Fabrication of glued wood products		x										x		VII, A-2-e
-5	Composite glued products fabrication							x		x			x		VII, A-2-e
-6	Particle board fabrication and use									x			x		VII, A-2-e
FS 3-b2	WOOD FINISHING														
-1	Painting and finishing wood		x										x		VII, A-2-g
-2	Deterioration of wood coatings														Inactive

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Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 3-b3	PROTECTION OF WOOD FROM FIRE														
-1	Increasing the fire safety of wood												x		VII, A-2-h
-2	Effects of heat in wood processing												x		VII, A-2-c
FS 3-c1	STRENGTH AND RELATED PROPERTIES OF WOOD														
-1	Strength properties of wood				x								x		VII, A-5-a
FS 3-c2	FACTORS AFFECTING STRENGTH														
-1	Factors affecting strength			x								x	x		VII, A-5-a
-2	Effect of temperature on strength										x		x		VII, A-5-a
-3	Methods of test												x		VII, A-5-a
FS 3-c3	PHYSICAL PROPERTIES OF WOOD														
-1	Electrical properties of wood												x		Not reported
-2	Vibration characteristics of wood												x		VII, A-5-a
FS 3-c4	PROPERTIES OF WOOD- AND FIBER-BASE MATERIALS														
-1	Properties of wood-base materials												x		VII, A-5-b
FS 3-c5	DESIGN AND CONSTRUCTION OF STRUCTURAL ELEMENTS														
-1	Design criteria for plywood												x		VII, A-5-c
-2	Laminated construction												x		VII, A-5-d

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		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
-3	Joints and fastenings							x					x		VII, A-5-c
FS 3-c6	DESIGN AND CONSTRUCTION OF STRUCTURES														
-1	Improved building construction												x		VII, A-5-d
-2	Moisture content of wood in use		x	x	x					x			x		Not reported
-3	Working stresses and stress grades				x					x			x		VII, A-5-d
-4	Farm woods for farm buildings												x		Not reported
FS 3-c7	SEASONING OF WOOD														
-1	Kiln drying schedules			x									x		VII, A-2-a
-2	Kiln mechanics and operation		x			x		x		x	x		x		VII, A-2-a
-3	Seasoning of wood poles														Inactive
-4	Air drying of lumber							x		x	x	x			Not reported
FS 3-d1	DESIGN AND CONSTRUCTION OF SHIPPING CONTAINERS														
-2	Fiber containers												x		VII, A-5-e
-4	Pallets							x					x		VII, A-5-e
-6	Container fastenings												x		VII, A-5-e
-7	Package cushioning materials												x		VII, A-5-e
-8	Wood containers												x		Not reported
FS 3-e1	HARVESTING THE TIMBER CROP														
-1	Wood-harvesting studies		x		x	x	x	x	x						VII, B-1, 2
-2	Log and tree grades		x	x	x	x	x	x	x	x	x		x		VII, A-1-c
-3	Small sawmill improvement				x	x	x	x	x	x	x		x		VII, A-2-a
-4	Mechanics of wood cutting												x		VII, A-2-c

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		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 3-e2	WOOD USE DEVELOPMENT														
-1	Machining of wood												x		
-2	Fabricated products yields from lumber							x					x		VII, A-2-b
FS 3-e3	STRUCTURE AND IDENTIFICATION OF WOODS														
-1	Structure and identification of woods									x			x		VII, A-1-a
FS 3-e4	RELATION OF GROWTH CONDITIONS TO WOOD QUALITY														
-1	Effect of environment on wood structure				x	x			x	x	x		x		VII, A-1-b
-2	Effect of silvicultural treatments on wood structure				x		x						x		VII, A-1-b
FS 3-e5	RELATION OF VARIATION IN WOOD STRUCTURE TO ITS PROPERTIES														
-1	Basic anatomical features affecting properties of wood									x			x		VII, A-1-a
FS 3-e6	EVALUATION OF THE WOOD STRUCTURE AND CHEMICAL COMPOSITION OF SUPERIOR TREES SELECTED FOR GENETICS STUDIES														
-1	Evaluation of superior trees												x		Not reported

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		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 3-f1	IMPROVING YIELD AND QUALITY OF PULPS														
-1	Pulping process investigations												x		VII, A-3-a
-2	Chemical and mechanical treatments for pulps												x		VII, A-3-b
-3	Fundamental properties of pulps and fibers												x		VII, A-3-a
FS 3-f2	DEVELOPING AND IMPROVING PULP AND PAPER PRODUCTS														
-1	Fabrication methods for paper and paperboard												x		VII, A-3-b
-2	Fabrication methods for wallboard												x		Not reported
-3	Composite pulp and paper products												x		VII, A-3-b
FS 3-f3	DIVERSIFICATION OF SPECIES AND UTILIZATION OF WOOD WASTE														(See)
-1	Pulping southern woods												x		FS-3-f1-1
-2	Pulping western woods												x		Not reported
-3	Pulping eastern and Lake States woods												x		VII, A-3-a
FS 3-g1	CHEMISTRY OF WOOD AND CELLULOSE														
-1	Chemical conversion of wood												x		VII, A-4-b
-2	Wood extractives												x		Not reported

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		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 3-g2	CHEMISTRY OF LIGNIN														
-1	Hydrogenation of wood														Inactive
-2	Chemistry of lignin												x		VII, A-4-a
-3	Chemical conversion of lignin												x		VII, A-4-a
FS 3-g3	PROCESS DEVELOPMENT														
-1	Pilot plant investigations												x		VII, A-4-e
-2	Charcoal production						x		x				x		VII, A-4-e
FS 3-g4	MICROBIOLOGICAL RESEARCH														
-1	Fermentation studies												x		VII, A-4-c
FS 3-g5	PHYSICAL CHEMISTRY OF WOOD AND WOOD PRODUCTS														
-1	Fundamentals of adhesion												x		VII, A-4-d
-2	Modified woods												x		VII, A-4-d
-3	Movement of vapors and solutions through wood									x			x		VII, A-4-d
FS 3-g6	ANALYSIS OF WOOD AND WOOD PRODUCTS														
-1	Chemical analyses of wood												x		VII, A-4-c

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VIII. FOREST ECONOMICS AND MARKETING RESEARCH

A. FOREST SURVEY

Problem

Up-to-date information on trends in the Nation's forest land and timber resources and on the outlook for timber supplies and demands is essential to guide the policies and programs of forestry agencies and the business policies of forest industries. Information needed includes basic inventory data on the area and condition of forest lands by various classes of ownership; the volume, quality and location of standing timber; trends in timber growth and mortality; and the present and prospective amount and kind of timber cut for industrial products. Because of rapid changes in resources resulting from growth, industrial cutting, and changes in land use there is need for periodic resurveys and analyses of the timber situation for all timber States and for the Nation as a whole. Continued progress and increased efficiency of inventories of the Nation's 775 million acres of forest land also depend on continuous development of improved survey methods and techniques for measuring and classifying forest land and timber, and for compiling and analyzing forest resource data.

Program

This continuing long-range program of applied research is conducted primarily through the field experiment stations of the Forest Service in close cooperation with State forestry agencies, wood-using industries and other cooperators who contribute manpower and funds. Essentially all of the 775 million acres of forest land in the United States has been inventoried at least once. Resurveys to provide up-to-date information and to determine trends in timber supplies, forestry problems and forest industrial development opportunities are being made in all States at intervals of from 8 to 15 years.

Research on timber inventories and industrial use of timber involve about 100 professional Federal man-years annually.

Progress

1. Resource Inventories and Analyses

a. Progress on forest inventories. During the past two years the nationwide Forest Survey has been completing inventories on an average cycle of about 11 years compared with an average goal of somewhat less than 10 years between Surveys. Surveys have been under way in all sections

of the country, including Alaska, California, Washington, Oregon, Idaho, Colorado, Wyoming, Tennessee, West Virginia, Missouri, Minnesota, Georgia, Hawaii, Arizona, Utah, Montana, South Dakota, Illinois, Maryland, Alabama, and North Carolina. Examples of information obtained on trends in the forest situation and forestry problems and opportunities are given in the following items.

b. Softwood resource in Arkansas increases. Resurveys of timber resources in Arkansas have shown more softwood but less hardwood timber than a decade ago. Total softwood timber volume in trees above 5.0 inches in diameter has increased 31 percent since 1951, while hardwood volume has declined 9 percent. The inventory of this growing stock now totals 12 billion cubic feet. In the same decade the volume of softwood sawtimber increased 41 percent while that of hardwood dropped 19 percent. Improved fire protection, conservative harvesting, and removal of low-value hardwoods on areas better suited to pine helped to increase the softwood. Much of this forestry effort was on public lands and holdings of wood-using industries. Localized land clearing and heavy cutting contributed to the decline of hardwoods on bottom lands. The survey also showed that forests cover 7 percent more forest land than in 1951, largely as a result of reversion of upland fields to forest.

c. Wisconsin's timber resources show mixed trends. Comparisons of data from the recent resurvey of Wisconsin with those from the first 1936 survey show both favorable and unfavorable trends. Forest lands are now better stocked, stand volumes are higher, and both growth and allowable cut are significantly larger than in 1936. Good forest management is practiced on more areas and fire losses have been greatly reduced. At the same time, serious deficiencies in important species and timber types remain. The acreage dominated by conifer stands is still less than 14 percent of the forest land. More than a million acres of nonstocked and poorly stocked forest land still exist. Much growing space is occupied by cull trees, and sawtimber trees average smaller in size and volume, especially for the more desirable sugar maple and yellow birch. The cut of major softwood species exceeds the allowable or desirable cut in most areas, particularly in central Wisconsin.

d. Timber potential of Southeast basins. A study of potential timber supplies and forest industrial development in the Southeast River Basins, a 90,000 square mile area which includes most of Georgia and small adjoining areas in North Carolina, South Carolina, Alabama, and Florida, was prepared for the Southeast River Basin Study Commission. Forest lands capable of producing commercial crops of timber cover some two-thirds of the total Basins' area. With prospective management annual growth of all growing stock trees may be expected to increase from 1.3 billion cubic feet in 1960 to 1.5 billion cubic feet in 1975, and to 1.9 billion cubic feet in the year 2000.

This projected growth could support large increases in employment and income from pulp and paper manufacture and other forest industries in the Basins.

2. Timber Cut

a. Pulpwood production trend upward. The rising trend in cut of pulpwood in the Lake States is illustrated by figures for 1960 which showed that pulpwood production exceeded 3.3 million cords for the first time--11 percent more than in the previous year and more than double that of ten years ago. The expansion of pulping capacity, especially in Michigan, and the use of larger proportions of local wood in Wisconsin were the factors largely responsible for bringing about the increase in production. In 1936 almost all pulpwood consumed in Wisconsin, for example, was softwood whereas in recent years, 73 percent consisted of aspen and other hardwoods. Plant residues also found increasing acceptance. Local pulpwood producers supply about 88 percent of the pulpwood used, Canada 10 percent and western States 2 percent.

Pulpwood production in the South also has been setting new records with 23.6 million cords produced in 1960, or 4 percent more than in 1959. Pine roundwood (bolts cut from standing timber) provided 16.5 million cords, hardwood roundwood 4.1 million cords and residues about 3 million cords. Hardwood pulpwood production was up 9 percent above the previous year and chips 21 percent.

b. Residue chips now major source of Northwest pulping material. In Oregon and Washington residues from lumber and plywood plants now provide more pulping materials by weight than logs and bolts. Use of residues increased from 9 percent of all pulping materials consumed in 1947 to 47 percent in 1958. During the same period consumption of logs decreased from 81 percent of all pulping materials used to 41 percent and bolts to 12 percent. There remains a significant potential for expanded use of residues in the Douglas-fir subregion where only about half of the 400 million cubic feet of residues annually available for chipping is being used.

3. Techniques Research

a. Stand classification techniques developed. A highlight of research in survey techniques was the development of methods for classifying stocking and prospective productivity of timberlands. This involves use of clusters of ten-point samples at each field plot location where timber volume, growth and area classification data are collected. This system provides a classification of trees by quality and vigor classes, a rating of regeneration prospects where restocking is inadequate, and a grouping of areas by stand treatment classes.

b. Aerial film types tested. Studies of films used in aerial surveys showed that significantly better photo interpretation of tree species could be accomplished on color film than on panchromatic photographs. Identifications of species made by several photo interpreters were more accurate and more consistent with color photographs than with black and white photographs. Guides for photo classification of several kinds of two-story stands in the Douglas-fir subregion, also were developed in the forms of a series of stereograms. These guides not only expedite the mapping of such stand on a consistent basis, but also provide graphic definitions of forest maps in that region. Results of another study indicated that aerial photographs of medium scale (1:12,000) were generally as satisfactory as larger, more expensive, scales for mapping and sales layouts required under unit area control management of ponderosa pine forests.

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B. FOREST ECONOMICS

Problem

The process of establishing, protecting and managing forest resources involves many questions of investments, costs and benefits that the landowner or public land manager must consider. Administrators of public forests must have a sound basis for decisions as to desirable combinations of uses of forest lands and timber and for management practices based both on biological principles and on economic considerations. Industrial foresters must develop recommendations and practices based on cost and return determinations within the framework of company policies and objectives. The 4-1/2 million farmers, businessmen, professional people, and other occupational groups who own in small parcels about 60 percent of the Nation's commercial forest land also make decisions on timber growing that are influenced to a large degree by economic considerations. Economics analyses are essential to develop concepts and principles for economic evaluation of alternative combinations of forest land uses and guides for profitable and efficient management of forest resources.

Program

The Department conducts a continuing long-term program of applied research primarily through the field experiment stations of the Forest Service. Close cooperation, joint effort and coordination of economics research with that of forest management research are essential in dealing with problems of timber growing; with forest fire, disease and insect research, and with National Forest Management and State and Private Forestry on problems of forest protection; and with forest, watershed and range management and recreation research on problems of competing and multiple uses of forest lands. Cooperation also is maintained with

the Economics Research Service, State Agricultural Experiment Stations and forestry schools to coordinate related programs by interchange of information, to consider mutual forest economics problems and occasionally to conduct cooperative investigations. The Federal effort devoted to research in this field totals 30 professional man-years annually.

Progress

1. Economics of Timber Growing and Protection.

   a. Returns on loblolly planting. --Preliminary guidelines have been developed for judging investment opportunities in planting loblolly pine in the South under varying conditions of initial land cost, site productivity, stand establishment costs, cutting schedules, and stumpage prices. Estimated returns on investments from planting pine on average or better sites range from 6 to 15 percent. A wide range of returns is possible, however, underscoring the need for careful land appraisals and ranking of forestry alternatives.

   b. Hardwood management in the Ozarks. --A study of costs and returns from management of hardwood timber stands on small timber ownerships in the Ozarks showed that under present costs, market conditions, and prices well-stocked managed hardwood timber stands can produce earnings comparable to long-term bonds. The same stands without management, however, do not yield significant net returns over a rotation period. Because of potentially greater yields, relatively high investments in management appear practical on pine sites and the better hardwood sites.

   c. Capital budgeting in forest management. --A study of practical applications of capital budgeting concepts in industrial forest management in the Pacific Northwest has provided a perspective on the opportunities for industrial forestry investments, the efficiency of capital in industrial forestry, and the need for a close accounting and analysis of forestry investment opportunities. The study also illustrates the dominant role of the rotation decision in the financial management of industrial forests and the importance of capital budgeting in the management of growing stock, development of forest roads, planning of cultural investments and reforestation of forest land.

   d. Economics of black spruce regeneration in Lake States. --An analysis of investment opportunities in regenerating black spruce in the Lake States demonstrated the importance of site and land value on regeneration investment decisions.

It was estimated, for example, that at discount rates of 2 percent, landowners can invest $20 per acre more on medium sites and almost $40 per acre more on good sites than on poor sites, given the same initial land values. Limits of investment depend upon the discount rate used, the land values, and stumpage price and cost expectations.

e. Returns from small woodlots. --Results of a ten-year study of management operations and financial returns from two 30-acre demonstration woodlots in West Virginia, showed comparative returns to forest owners who do their own logging and killing of cull trees, owners who hired loggers but killed cull trees, owners who paid for both the logging and killing of culls, and owners who purchase land and pay for logging and cull tree killing. The methods described are applicable in aiding forest owners evaluate their own specific opportunities in managing small holdings.

f. TSI returns in Rocky Mountains. --A study in the Northern Rocky Mountain region showed that with present cost and value levels each dollar spent in thinning will produce an estimated $4 to $45 in added yields by rotation age, while each dollar spent in pruning would produce an estimated $9 to $40 of extra value. The most valuable species on the best sites promise to return rates of interest that are currently thought to be reasonable for long-term investment.

2. Evaluation of Multiple-Use Problems.

a. Beaver Creek project. --Since 1956, stream gauges have been installed in 17 sub-watersheds of a 275,000-acre pilot area in the Coconino National Forest in Arizona. Treatments to date include complete removal of pine and other trees from a 150-acre sub-watershed in the ponderosa pine type and reseeding to grass at a cost of $95 per acre. More than 6,000 acres of pine have been treated by thinning and other TSI measures at costs from $12 to $27 per acre. More than 16,000 acres of pinyon-juniper stands have been cleared and planted to grass at about $13 per acre. Expanded and additional treatments will be applied as additional watersheds are adequately calibrated. Preliminary results on treatment costs and effects of treatment on water, timber, forage and other resource yields are already providing helpful guides for management of large land areas in the critical watersheds of the Southwest.

3. Programs for Small Ownerships.

a. Characteristics of small woodland owners. --Interviews with owners of small forest tracts at nine widely-separated localities in the eastern United States indicated that the majority of forest owners are farmers who own less than 100 acres; live within a reasonable distance of their forest property; and show a considerable variation in length of tenure. A minority apply forestry practices on their tracts or make use of the services of professional foresters. A very small percentage have obtained ACP payments, sought credit or insurance or leased their forest land for management purposes. Few consider forest land and timber taxes a deterrent. The percentage of owners holding a favorable attitude toward forestry definitely increases with size of forest land ownership.

b. Factors motivating small woodland owners. --The findings of two Michigan studies emphasize the importance of fully analyzing all physical, economic, and social factors before proposing or implementing forestry aid and assistance programs in a local area. In the upper peninsula, absentee owners who hold land primarily for recreation use are becoming increasingly important, while in southern Michigan wage earners, business and professional people, retirees, and other nonfarmer groups together represent the largest part of the small owner population. Urban expansion in southern Michigan has changed forest use and widely influenced ownership expectations and land use plans. Such factors must be considered in developing programs intended to promote better forest management among private owners.

c. Watershed rehabilitation program. --An appraisal of progress on the largest land rehabilitation project in the Nation in the eroded Yazoo-Little Tallahatchie Watershed of Mississippi, showed that the program has had considerable success in encouraging landowners to improve their woodlands. Owners with above average assets responded best, but low income owners have also participated substantially. Major reasons for progress are the cooperation of all agricultural agencies, local consideration of owner characteristics and farm capabilities, public sharing of conservation investments and services of trained technicians who visit owners and provide technical services.

d. Forest finance. --A study in northeastern Wisconsin to develop an improved forest land and timber assessment classification for use under the general property tax showed little or no

correlation of sale prices of timberlands with classifications based either on timber characteristics such as stand-size class, species composition and stand density or on other factors such as nearness to markets, transportation facilities, nearness to lakes or streams and size of property. It is evident that other factors not measured or lack of knowledge on the part of buyers currently are responsible for differences in selling prices.

A comprehensive review of forest tax development over the twenty-five year period 1935-1960 was published, covering property taxes, yield taxes, severance taxes, income taxes and death taxes. This analysis and interpretation of emerging developments in the forest tax field summarizes changing taxing practices and probable developments.

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C. FOREST PRODUCTS MARKETING

Problem

About 60 percent of the Nation's commercial forest land is owned by about 4-1/2 million farmers and other small landowners. For many of these owners information is not readily available on timber markets, prices for different species and qualities of timber and effective procedures for marketing timber to best advantage. As a result, forest incomes are often relatively low and incentives to good forest management consequently lacking. In the timber industries there are likewise large numbers of loggers and plant operators faced with problems of inefficient production methods, limited outlets for products, and marketing systems that often result in relatively low returns to producers and uncertain service to consumers of forest products.

Marketing systems and practices need to be improved by studies to determine the relative efficiency of alternative marketing practices, the optimum combinations of products obtainable from available timber, and the economic possibilities of group arrangements to overcome the difficulties of small scale operations. Market development studies are needed to determine quantities and locations of surplus species and qualities of timber, including residues, and the economic feasibility of new or expanded industries based on their use. Strengthened research on wood consumption and trends in timber requirements is needed to indicate future markets and prospective resources problems and to guide forest policies and programs aimed at keeping the Nation's timber budget in balance.

Program

This is a continuing program of applied research conducted in part by the regional experiment stations and partly by the Washington staff. Close cooperation is maintained with other scientists, particularly in forest products and engineering research in coordination of research on mutual problems and in joint conduct of some studies. Cooperation also is maintained with the Agricultural Price Statistics Branch of the Statistical Reporting Service, State Agricultural Experiment Stations, forestry schools, and various forest products trade associations in the exchange of information and participation in cooperative studies. Forest owners, loggers, mill operators and wood consumers cooperate by permitting access to active operations for the collection of processing and marketing data.

The Federal effort devoted to research in this area totals 40 professional man-years annually.

Progress

1. Marketing Systems and Practices

   a. Remanufacturing increases returns. --A study of 50 eastern Kentucky lumber producers has shown how additional plant investments and processing beyond rough green lumber increases product value, labor force required, and returns to the community. For example, two plants each using 2 million board feet of timber annually show the following financial comparison:

Plant costs & returns	Plant producing rough lumber only (Dollars)	Plants doing further processing (Dollars)
Expenditures		
Stumpage purchases	35,200	35,200
Payroll	44,500	102,900
Equipment	11,200	41,800
Power	6,000	13,000
Other	7,600	17,000
Total	104,500	209,900
Receipts	123,900	259,600
Margin	19,400	49,600

Such information has been requested from many sources in connection with area Redevelopment Programs.

b. Scaling sawlogs by weight. --A study of log-scaling by weight for loblolly and shortleaf pine logs indicated that scaling by weight promises equal accuracy and greater day-to-day consistency in estimating and selling logs than scaling by traditional log-rule methods using the Doyle, Scribner Decimal C., or International log rules. Weighing by truckloads resulted in a relatively high degree of accuracy and substantial savings in time and money.

c. Stumpage price determinants analyzed. --Prices of pine pulpwood stumpage on National Forests in the midsouth vary widely by price zones, according to an analysis of 377 sealed-bid pulpwood sales made from 1955 through 1960 on national forests in six States. Prices per cord ranged from $1.75 to $8.38, averaging $4.87. Most of the price variation was associated with four factors: (1) local competition, (2) changes in demand for pulpwood over time, (3) stand conditions, and (4) kind of wood. For each additional company buying wood in an area, prices averaged about 20 cents more a cord. Stumpage within truck haul of a mill brought higher prices also. Prices rose with tree size and cut per acre and declined where top wood was included in a sale.

Another study of hardwood sawtimber stumpage sales in eastern Kentucky showed that average tree volume and percent of preferred species in a sale accounted for 30 to 40 percent of stumpage price variations. In addition to guiding appraisals, this study provides a means of improving price reports by subdividing the "mixed sawtimber" classification.

In a study of 522 sales of sawtimber stumpage on National Forests between 1949 and 1958, current wholesale lumber prices, trend in lumber prices, and the grade and size of the average tree influenced numbers of bids and prices received. Evidence from this study indicated that information on grade of timber sold is of major importance for accurate appraisals and for price and market reports.

A related analysis of stumpage prices for southern pine sawtimber in South Carolina marked by State CFM foresters showed that of 23 variables tested for their relationship to price, the four most significant factors were (1) average volume per tree, (2) road distance to nearest stationary sawmill or planing mill, (3) number of bids received, and (4) geographic location of tract.

d. Price structure of southern pine lumber changing. --Shifting market demands have altered the price structure of southern pine lumber. In the last 10 years wholesale prices for B and better southern pine lumber have dropped almost 20 percent while prices of dimension and structural timbers have risen somewhat. For many manufacturers, lower prices for B and better lumber have intensified the profit squeeze caused by rising wages and other costs and have induced operators to improve mills and to increase output of 2-inch lumber. The changing price structure also has reduced somewhat the relative value of upper-grade logs and high-quality stumpage.

e. Buying and selling practices of sawmills in Central States. --A study of timber purchasing and selling activities of Ohio sawmill operators showed that 69 percent of the raw material used was purchased as standing timber and only 31 percent as logs. The major market for lumber sawn by these operators was the furniture and allied secondary wood-using industries. A related study showed that most sawmills that were operated full-time manufactured most of their hardwood logs into factory grade lumber. Average production was about 1,000 board feet per man-day. Mills that produced lumber primarily for pallets and local use averaged about 10 percent more production per man-day. More than 70 percent of the lumber manufactured by mills specializing in factory lumber was sold to markets between 50 and 500 miles distant. Mill prices during 1960 averaged $96 per M bd. ft. for factory grade lumber, $66 for pallet, blocking and dimension lumber, and $63 for construction and local use lumber.

f. Lumber industry mergers increase. --Merger activity in the lumber industry proceeded at an accelerated pace during the decade of the 1950's, surpassing that of any other manufacturing industry in the United States. Of the 20 largest firms producing lumber in the Douglas-fir subregion in 1947, 8 disappeared through the merger process, 3 ceased operations entirely, and 1 became a cooperative. In both the Douglas-fir subregion and the Nation, the merger movement produced a significant increase in concentration of production over the period 1954-1959. Although concentration of production and timber ownership has increased substantially, the lumber industry remains one of the most competitive industries in the entire United States economy.

2. Market Development

a. Hardwood timber available in North Carolina. --A study of timber supplies in the southern Piedmont of North Carolina indicates that the hardwood growing stock is rapidly increasing in supply and can provide the base for new or expanded wood-using industries. The bulk of the surplus growth is made up of yellow-poplar, sweetgum, and white oak. These species comprise 56 percent of the hardwood sawtimber supply and account for 77 percent of the net increase in inventories between 1937 and 1955.

b. Markets limited for hardwood timber in Ohio. --A study in a 26-county area of southeastern Ohio indicates that the available growth of hardwood sawtimber is about 2-1/2 times the current cut. The study area contains 60 percent of the State's forest land yet supports only 20 percent of the State's wood-using industries. Factors limiting expansion of industry in the area include the low quality of the hardwood timber available, the many small ownerships of timberland, and a lack of investment capital.

c. Forest industry prospects in West Virginia. --Establishment or expansion of wood-using plants in the Beckley-Hinton area of southern West Virginia appears promising, according to a preliminary report on timber marketing prospects in West Virginia. There is a sizeable and increasing wood supply of relatively good quality, water supplies are adequate for moderate-size pulpmills, industrial sites and utilities are readily available, and local financial assistance is available under a new Industrial Development Authority.

d. Southern markets help southern pine. --An analysis of southern pine lumber distribution patterns shows that expanding markets in the South have partially offset a persistent decline in shipments to historic markets in the North. Some 55 percent of the southern pine lumber cut is now being used within the State of origin and much of the remainder goes to a neighboring State. Among the causes for declining Northern shipments have been increasing competition from the West and rising freight rates for southern lumber.

e. Timber salvage by advance roading. --Current mortality on some 3 million acres of old-growth Douglas-fir timber lands in the Pacific Northwest approximates one billion board feet annually. Recent studies indicate the economic practicability of constructing roads in such stands well in advance of final harvest. Interest,

maintenance charges and depreciation on the capital outlay for such roads in numerous cases can be met by returns obtained from timber salvage. The principal factors affecting net returns from advance roading include timber quality and degree of stand decadence, species composition, and the costs of salvage logging as affected by accessibility and salvable volume.

f. Logging residues in eastern Oregon. --A classification of logging residues in eastern Oregon, made to determine the economic feasibility of utilizing this material, indicated that because of such factors as small volumes of residues per acre and the knotty character of much of the residues, there was little current opportunity for economic use of this raw material.

3. Demand Analyses and Projections

a. Wood use in housing. --As part of a continuing program of studies of present and potential timber requirements, comprehensive information on use of wood products in FHA-financed residential construction has been obtained from offices throughout the United States. This has indicated, for example, that in 1959 seven out of ten FHA inspected houses in the Nation were of wood frame wall construction. Four out of ten were built on a concrete slab. Other characteristics varied widely from region to region. When completed, this study will provide information on the amounts and kind of timber products used in house construction and on the ways this use is affected by differences in type of construction, structure size, construction cost, and geographic location.

b. Wood use by transportation industries. --A survey of selected transportation industries, including packing and crating, trucking, and water-borne shipping industries, showed that in 1958 an estimated $15.7 million was spent for lumber and plywood and $4.7 million for wooden containers and pallets. Of the lumber purchased, 62 percent was used for dunnage, bracing and blocking; 22 percent for boxes and crates; 12 percent for repair and maintenance of trucks, and the remaining 4 percent for pallets. Industries concerned with ocean-borne shipping, including both the ship companies and stevedore firms, used 60 percent of the lumber, trucking companies 22 percent, and packing and crating firms about 14 percent.

c. Wood use on farms. --In central Minnesota, a pilot study of farm use of lumber showed an average annual use of 100 board feet of lumber for repair and 500 board feet for new construction. About 78 percent of the repair lumber and 60 percent of the lumber for new construction consisted of native hardwoods from local woodlots. Gross farm income, indicating ability to purchase and expand operations, turned out to be the best indicator of lumber consumption. A similar study of wood use in rural areas of Missouri showed that farmers and other rural dwellers in that area annually consume about 1,100 board feet of lumber per farm, 3.6 square feet of plywood, 4.6 cords of fuelwood, and 133 fence posts.

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WORK AND LINE PROJECTS, Forest Economics and Marketing Research DIVISION
FOREST SERVICE, U. S. D. A.

Reporting Year May 1, 1961 - April 30, 1962

Work and Line Project Number	Work and Line Project Short Title	Research Locations During Year [1]												Line Project Summary Index
		NOR	PNW	PSW	INT	RM	LS	CS	NE	SE	SO	ITF	FPL	WO	
FS 4-s1	FOREST SURVEY														
-1	Demand for forest products										x			x	VIII, C-3
-2	Forest inventories	x	x	x	x		x		x	x	x			x	VIII, A-1 & 2
-3	Timber processing and distribution capacity														
-4	Survey techniques		x		x									x	VIII, A-3
FS 4-e1	FOREST ECONOMICS														
-1	Economics of timber production		x	x	x		x	x	x	x	x				VIII, B-1
-2	Economics of forest protection		x						x						
-3	Economics of forest land use		x	x	x	x									VIII, B-2
-4	Forest land ownership		x				x	x	x	x	x				VIII, B-3
-5	Forest finance						x				x			x	VIII, B-3-d
FS 4-m1	FOREST PRODUCTS MARKETING														
-1	Price and market information							x		x	x			x	VIII, C-1-c, and 1-d
-2	Marketing practices		x		x		x	x	x	x	x				VIII, C-1-a, 1-b, 1-e, 1-f
-3	Market development		x		x	x			x						VIII, C-2
-4	Timber quality standards			x					x						

[1] Research Locations

NOR	- Northern	INT	- Intermountain	CS	- Central States	ITF	- Institute of Tropical Forestry
PNW	- Pacific Northwest	RM	- Rocky Mountain	NE	- Northeastern	FPL	- Forest Products Laboratory
PSW	- Pacific Southwest	LS	- Lake States	SE	- Southeastern	WO	- Washington - Beltsville
				SO	- Southern		